THE

GEOLOGICAL MAGAZINE

NEW SERIES.

DECADE III. VOL. IV.

JANUARY—DECEMBER 1887.

THE

GEOLOGICAL MAGAZINE:

OR,

Monthly Journal of Geology:

WITH WHICH IS INCORPORATED

"THE GEOLOGIST."

NOS. CCLXXI. TO CCLXXXII.

EDITED BY

HENRY WOODWARD, LL.D., F.R.S., V.P.G.S., F.Z.S., F.R.M.S.,

OF THE BRITISH MUSEUM OF NATURAL HISTORY;

VICE-PRESIDENT OF THE PALÆONTOGRAPHICAL SOCIETY,

MEMBER OF THE LYCEUM OF NATURAL HISTORY, NEW YORK; AND OF THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA; HONORARY MEMBER OF THE YORKSHIRE PHILOSOPHICAL SOCIETY; OF THE GEOLOGISTS' ASSOCIATION, LONDON: OF THE GEOLOGICAL SOCIETIES OF EDINBURGH, GLASGOW, HALIFAX, LIVERPOOL, AND NORWICH; CORRESPONDING MEMBER OF THE GEOLOGICAL SOCIETY OF BELGIUM; OF THE IMPERIAL SOCIETY OF NATURAL HISTORY OF MOSCOW; OF THE NATURAL HISTORY SOCIETY OF MONTREAL; AND OF THE MALACOLOGICAL SOCIETY OF BELGIUM.

ASSISTED BY

ROBERT ETHERIDGE, F.R.S. L. & E., F.G.S., F.C.S., &c.,

OF THE BRITISH MUSEUM OF NATURAL HISTORY.

WILFRID H. HUDLESTON, M.A., F.R.S., Sec.G.S.

AND

GEORGE J. HINDE, Ph.D., F.G.S., &c.

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LONDON:

TRÜBNER & Co., 57 AND 59, LUDGATE HILL.

F. SAVY, 77, BOULEVART ST.-GERMAIN, PARIS.

1887.

HERTFORD:
PRINTED BY STEPHEN AUSTIN AND SONS.

Geology
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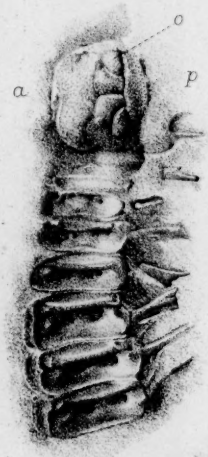

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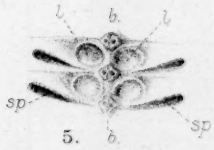

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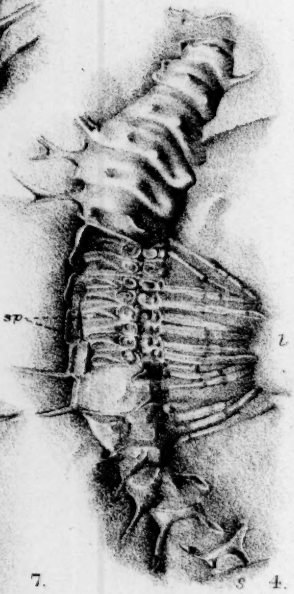

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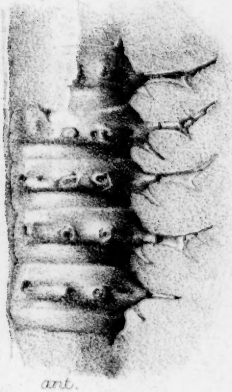

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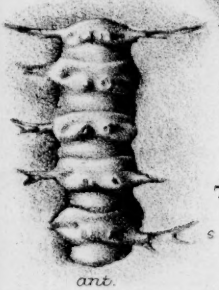

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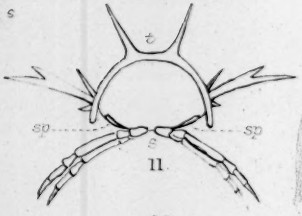

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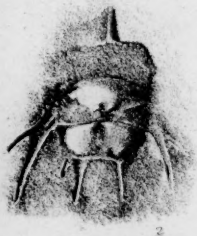

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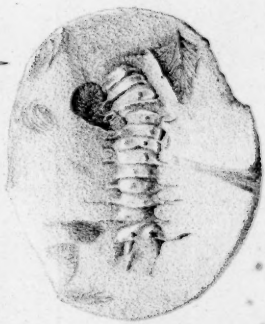

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G. M. Woodward del. et lith. West, Newman & Co. imp.

Carboniferous Myriapods.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. IV.

No. I.—JANUARY, 1887.

ORIGINAL ARTICLES.

I.—On some Spined Myriapods from the Carboniferous Series of England.

By Henry Woodward, LL.D., F.R.S., F.G.S.

(PLATE I.)

PALÆONTOLOGISTS are largely indebted to Messrs. Meek and Worthen for their very careful researches in the Coal-Measures of Illinois, which have resulted in such large and valuable accessions to the fauna and flora of the Carboniferous formation. Not the least interesting of these has been the discovery of numerous organisms, which were first recognized and correctly described by them in 1868[1] as the remains of spined Myriapods.

The earliest record of the discovery of one of these curious terrestrial Arthropods in England will be found in "A History of Fossil Insects," etc., by the Rev. P. B. Brodie, M.A., F.G.S., 8vo. 1845, in the "Introductory Observations" to which Prof. J. O. Westwood drew attention to a figure (pl. i. fig. 11) in that work, representing a remarkable fossil preserved in a nodule of clay-ironstone from the Coal-measures, Coalbrook-dale, which he believed to be probably the remains "of some large Caterpillar furnished with rows of tubercles" (pp. xvii, 105, and 115, *op. cit.*). The specimen is preserved in the "Hope Collection," in the University Museum, Oxford (Woodcut Fig. 1).

The next specimen was figured and described by the late Mr. J. W. Salter, F.G.S.,[2] eighteen years later, who named it *Eurypterus* (*Arthropleura*) *ferox*, sp. nov., and referred to it as "one of the most curious *Crustacean* fragments on record," and as "part of the abdomen of a *Eurypterus*" (*op. cit.* p. 87). It was obtained from the clay-ironstone of the Staffordshire Coal-field at Tipton, from the shale over the "Thick-Coal" (Woodcut Fig. 2). Mr. Salter states that "another specimen occurs in the Hope Collection at Oxford."

So far back as 1859,[3] Prof. (now Sir) William Dawson, K.C.M.G., F.R.S., described a Chilognathous Myriapod from the Coal-measures of Nova Scotia, under the name of ***Xylobius sigillariæ*.**

[1] Geol. Surv. Illinois, vol. iii. pp. 558—559.
[2] Quart. Journ. Geol. Soc. 1863, vol. xix. p. 86, fig. 8.
[3] Quart. Journ. Geol. Soc. vol. xvi. p. 268.

This form did not, however, appear to have been provided with spines, like those from Illinois, discovered by MM. Meek and Worthen.

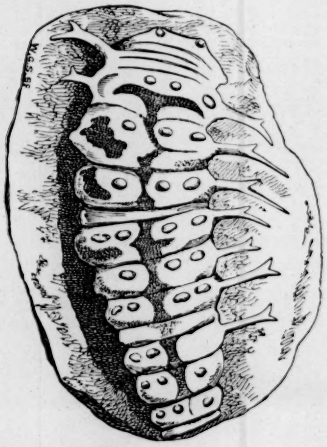

FIG. 1. *Euphoberia ferox*, Salter, sp. = *Acantherpestes Brodiei*, Scudder. (Copy of Brodie's original figure.)

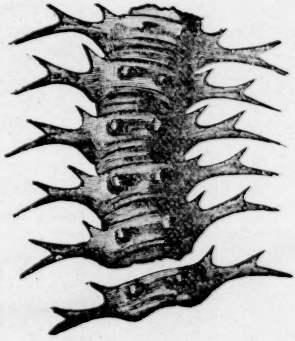

FIG. 2. *Euphoberia ferox*, Salter, sp. (Salter's original woodcut.) [1]

[Having been kindly permitted by Prof. J. O. Westwood to examine the original specimen in the "Hope Cabinet," I am able to state that the supposed extra row of tubercles are not the bases of spines broken off, but are *depressions* in the tergum near the base of each of the great branched spines, and may be seen near the lateral borders of each somite, in every specimen of *E. ferox* which I have examined.]

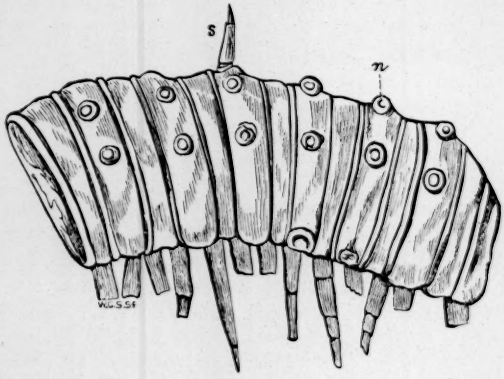

FIG. 3. *Acantherpestes major*, M. and W., Coal-measures, Illinois.

Neither did the specimen which I described in 1866,[2] from the Clay-ironstone of the Coal-measures, Kilmaurs, Ayrshire; which so closely resemble Dawson's specimen, that I referred it to even the same genus and species.

[1] Not an accurate representation of the fossil described by Salter.

[2] Trans. Glasgow Geol. Soc. vol. ii. pp. 234–238, pl. iii.

Mr. S. H. Scudder,[1] however, has changed the name to *X. Woodwardii*, on the ground that the marks which I interpreted as probably the openings of tracheæ, are in reality "the scars or bases of spines, which appear as warts or tubercles in many of the Mazon Creek Myriapods; or, when viewed from the interior surface, as pits" (*op. cit.* p. 149).

In 1868, Messrs. Meek and Worthen[2] described several well-preserved remains of spined Myriapods from the Ironstone nodules of Mazon Creek, Illinois (see Woodcut, Fig. 3), which are placed by Scudder in five genera and twelve species (see *infra*).

In 1871, I figured another Myriapod from the Clay-ironstone of the Coal-measures, Kilmaurs, Ayrshire, under the name of *Euphoberia Brownii*.[3] In that paper I compared *E. Brownii*, mihi, with *E. armigera*, M. and W., and stated, "There are indications of pores, and also of the bases of tubercles or spines, along the dorsal line, but the latter are less perfectly preserved."

In 1882, Mr. S. H. Scudder[4] summarized our knowledge of the Myriapoda of the Carboniferous formation, and added several new species, in addition to proposing a classification for those already described.

Later on (1884[5]), Scudder described three species of a new genus of Myriapods (*Trichiulus*), and gave a description of another Myriapod which had first been noticed under the name of *Palæocampa anthrax* by Messrs. Meek and Worthen in 1866, and for which he proposed, in 1884, a new suborder, viz. PROTOSYNGNATHA.

This form of Myriapod is remarkable on account of the dorsal plates supporting several longitudinal rows of fascicles of needle-like spines, giving it the appearance of a hairy Caterpillar of the "Tiger-moth" (*Arctia caja*).[6]

The body-segments have a single dorsal and ventral plate, the latter bearing a pair of widely-separated, stout, fleshy legs, one pair to each segment behind the head. These stout fleshy legs of *Palæocampa* remind one of the legs of *Peripatus*, but that genus has no hard tergal covering to its segments, as was the case in the fossil form.

All the other Palæozoic Myriapods are included by Scudder in his suborder ARCHIPOLYPODA.

These Myriapods have a more or less cylindrical body, the head is slightly larger than the body-segments, being composed of probably three or more coalesced segments, and bearing, as in other forms, a single pair of antennæ, a pair of compound eyes, mandibles, maxillæ and having the first pair of post-cephalic appendages directed forward, probably to assist in the process of feeding. The dorsal portion (tergum) of each somite or segment of the body is composed

[1] Mem. Boston Soc. Nat. Hist. 1882, vol. iii. no. v. p. 148.

[2] Amer. Journ. Sci. Arts, vol. xlvi. p. 25. See also Geol. Surv. Illinois, iii. 556.

[3] See GEOL. MAG. Vol. VIII. p. 102, Pl. III. Fig. 6 *a*, *b*, *c*.

[4] Mem. Boston Soc. Nat. Hist. vol. iii. no. v. pp. 143–182, pl. x.–xiii.

[5] Mem. Boston Soc. Nat. Hist. vol. iii. no. ix. 1884, "On two new and diverse types of Carboniferous Myriapods," pp. 283–297, pl. xxvi. and xxvii.

[6] Scudder's *Trichiulus villosus* was also covered with fine hairs; but this supposed Myriapod now proves to be the circinate vernation of a fern!

of only a single plate; but the ventral portion (sternum) is seen to be composed of two narrow parallel plates; and as each somite bears two pairs of legs, and two pairs of spiracles, it seems certain (says Claus) "that they may be regarded as double-segments,[1] formed by the fusion of two somites."

The raised anterior portion of the tergum of each segment is provided with a series of spines or tubercles, which, in some of the Mazon Creek specimens, are doubly-forked.

The class MYRIAPODA, at the present day, is divided as under, viz.:—

I. CHILOPODA (*Centipedes*). Antennæ simple, body depressed, dorsal and ventral plates horny, united by a membrane; the legs inserted in single pairs at the sides of the segments, with the exception of the first two pairs, which are converted into mouth-organs.

II. DIPLOPODA = CHILOGNATHA (*Millipedes*). Antennæ simple, body convex, or even cylindrical, the dorsal plates bent round so as to meet the narrow ventral plates nearly in the middle line of the body; each segment after the 5th or 6th with two pairs of legs.

III. PAUROPODA. With branched antennæ.

If we take the broadest possible lines for our guidance in the classification of animals, it seems that Scudder's PROTOSYNGNATHA will fall under the first of these divisions, viz.:—

Order I. CHILOPODA (*Centipedes*, recent).

Suborder PROTOSYNGNATHA (*Palæocampa*, fossil),

and his ARCHIPOLYPODA will in the same manner find a place under

Order II. DIPLOPODA (*Millipedes*, recent).

Suborder ARCHIPOLYPODA (all Palæozoic forms), with the following species:—

1. Family ARCHIDESMIDÆ, Peach.

Genus *Archidesmus*, Peach.
1. ,, *Macnicoli*, Peach, Old Red Sandstone, Forfarshire.

„ *Kampecaris*, Page.
2. ,, *Forfariensis*, Page, Old Red Sandstone, Forfar.

2. Family EUPHOBERIDÆ, Scudder.

„ *Acantherpestes*, Meek and Worthen, 1868.
3. ,, *major*, Meek and Worthen, Coal-measures, Illinois, U.S.
4. ,, (*Brodiei*, Scudder, Coal-measures, Coalbrook-dale.[2])

„ *Euphoberia*, Meek and Worthen, 1868.
5. ,, *ferox*, Salter, Coal-measures, Staffordshire.
6. ,, *horrida*, Scudder, Coal-measures, Illinois, U.S.
7. ,, *armigera*, Meek and Worthen, Coal-measures, Illinois, U.S.
8. ,, *Brownii*, H. Woodward, Coal-measures, Ayrshire.
9. ,, *granosa*, Scudder, Coal-measures, Illinois, U.S.
10. ,, *Carrii*, ,, ,, ,,
11. ,, *flabellata*, ,, ,, ,,
12. ,, *anguilla*, ,, ,, ,,

[1] *Not* originated from a fusion of two primitively distinct segments, but from a later imperfect division of each of the primitive segments into two, and the supply to each of the divisions of a primitive segment of a complete set of organs."—(Balfour, Embryology, vol. i. p. 392.)

[2] This is shown to be merely *E. ferox*, Salter, sp.; see ante p. 2, and infra p. 6.

Genus *Amynilyspes*, Scudder, 1882.
13. ,, *Wortheni*, Scudder, Coal-measures, Illinois, U.S.
,, *Eilecticus*, Scudder, 1882.
14. ,, *anthracinus*, ,, ,, ,,

3. Family Archijulidæ, Scudder.

Genus *Trichiulus*, Scudder, 1884.
15. ,, *villosus*, Scudder,
16. ,, *nodulosus*, Scudder,
17. ,, *ammonitiformis*, Scud.
} Recently shown by Scudder to be founded on the circinate vernation of a fern. (See Mem. Boston Soc. Nat. Hist. vol. iii. No. xiii. p. 438, 1886.)

,, *? Archiulus*, Scudder (*Julus*, Dohrn).
18. ,, *Brassii*, Dohrn, Rothliegendes, Lebach.
19. ,, *xylobioides*, Scudder, Coal-measures, Nova Scotia.
20. ,, *constans*, Frič ,, Bohemia.
21. ,, *costulatus*, Frič ,, ,,
22. ,, *pictus*, Frič ,, ,,
,, *Anthracerpes*, Meek and Worthen.
23. ,, *typus*, Meek and Worthen, Coal-measures, Illinois, U.S.
,, *Palæojulus*, Geinitz.
24. ,, *dyadicus*, Gejnitz, Dyas, Saxony.
} Founded on the circinate vernation of a fern.
,, *Scolecopteris*.
25. ,, *elegans*, Zenker, Coal-measures Germany.
,, *Xylobius*, Dawson, 1859.
26. ,, *sigillariæ*, Dawson ,, Nova Scotia.
27. ,, *Woodwardii*, Scudder ,, Ayrshire.
28. ,, *similis*, Scudder ,, Nova Scotia.
29. ,, *fractus* ,, ,, ,,
30. ,, *Dawsoni* ,, ,, ,,
31. ,, *Chonionotus lithanthraca*, Jordan, Coal-measures, Germany.

In a table prepared by Mr. Scudder for Prof. Dr. Zittel's Handbuch der Palæontologie,[1] of the fossil Myriapods, he places all the Palæozoic forms (save one) in his suborder Archipolypoda, namely, two Devonian species, thirty-one Carboniferous,[2] and four Dyas (?). The exceptional form belongs to his suborder Protosyngnatha.

He records one Diplopod from the Chalk-formation, seventeen Chilopoda, and twenty-three Diplopoda, from the Oligocene: one of the latter from the Miocene and forty-nine recent.

In the past year (1886) the British Museum (Natural History Branch) acquired the well-known collection of the late Mr. Henry Johnson, F.G.S., Mining Engineer, of Dudley, who had devoted the best years of his life to the collection of the fossils from the Wenlock Shale of his native place and those of the surrounding Coal-fields, particularly the Clay-ironstone nodules of the Coal-measures of Coseley, near Dudley, from the "Binds" between the "Brooch" and "Thick-Coal." From these he obtained a rich collection of Crustacean and Insect remains and also many spined Myriapods.

I exhibited the Insects and Myriapods at the British Association Meeting, Birmingham, in Section C. (Geology); and I was favoured with an opportunity to examine the rich collection of Silurian and Carboniferous fossils in the Museum of Mr. C. Beale, of Lime Tree House, Rowley Regis, not far from Dudley. Mr. Beale kindly placed

[1] Handbuch der Palæontologie von Karl A. Zittel, München. I. Abtheilung, II. Band, V. Lieferung—Myriopoda, Arachnoidea, und Insecta. Bearbeitet von Samuel H. Scudder (1885).

[2] These numbers must now be reduced by four Carboniferous and one Dyas species.

eight specimens of spined Myriapods in my hands, all enclosed in Clay-ironstone nodules similar to those in the Johnson collection.

Mr. Beale's specimens were obtained from the shales or Clay-bands at the top of the Brooch-coal, Sedgley, near Dudley.

These ironstone-nodules are considered to occupy a much higher horizon in the Coal-measures than those described by Prof. Prestwich in his Geology of the Coalbrook-dale Coal-field (Trans. Geol. Soc. Lond. 2nd ser. vol. v. pl. xli. 1840), but many of the organisms are identical from both areas.

EUPHOBERIA FEROX, Salter, sp., 1863. (Pl. I.)

"A Caterpillar?" Westwood in Brodie's Fossil Insects, 1845, p. xvii, 105, pl. i. fig. 11.

Eurypterus ? (*Arthropleura*) *ferox*, Salter, Quart. Journ. Geol. Soc. 1863, vol. xix. p. 86 (woodcut, fig. 8, reproduced on p. 2, *ante*).

Euphoberia ferox, Meek and Worthen, Geol. Surv. Illinois, vol. iii. (Palæontology) ("A Myriapod!").

Euphoberia ferox, H. Woodward ("A Myriapod!"). See Brit. Foss. Crustacea, order Merostomata, Pal. Soc. Mon. 1872, p. 173.

Euphoberia ferox, Scudder, 1882, Mem. Boston Soc. Nat. Hist. vol. iii. no. v. p. 157.

Euphoberia ferox, H. Woodw., 1873, GEOL. MAG. Vol. X. p. 112 (and 2 woodcuts).

Acantherpestes Brodiei, Scudder, 1882, *op. cit.* p. 156.

I am disposed to refer the whole of the 20 specimens of spined Myriapods, now under consideration, from the Staffordshire Coal-field (most of which have both impression and counterpart preserved) to one species, namely, to *Euphoberia ferox*.

In my monograph on the MEROSTOMATA (Pal. Soc. 1872, p. 173) I placed Salter's "*Eurypterus ferox*" with the MYRIAPODA,[1] and in the genus *Euphoberia*, as suggested by Messrs. Meek and Worthen. In this conclusion Scudder agreed in 1882, but he eliminated the specimen referred to in "Brodie's Fossil Insects" as a "Caterpillar," although Salter and I had both considered it as *identical* with *Euphoberia ferox*, and he has placed it in the genus *Acantherpestes*, making for it a new species, *A. Brodiei*. There are, however, no grounds for either the generic or specific separation of this fossil from *E. ferox*, save the obscurity of the specimen and the indistinctness in character of the original figure, from which all the subsequent ones have been *merely copies*.

From the excellent materials now collected together, in which are included the Johnson and Beale Collections, also Brodie's and Salter's original specimens, lent to me for examination by the kindness of Prof. J. O. Westwood, M.A., from the Oxford Museum, and Dr. A. Geikie, F.R.S., from the Museum of Practical Geology, Jermyn Street, I hope to be able to give some additional details which may assist towards a complete knowledge of this remarkable spined Myriapod from the English Coal-measures.

In four of the specimens the head is seen, and in two of these the details can be clearly made out, but the remaining ones are somewhat obscure and imperfect.

[1] Scudder, however, in his Memoir (*loc. cit.*), 1882, p. 157, cites me as still considering it to be a *Eurypterus*, whereas I most clearly state: "I am fully disposed to agree with Meek and Worthen, and to refer it to the *Myriapoda* and to their genus *Euphoberia*, feeling certain that it has *no relation whatever* to *Eurypterus*" (Pal. Soc. Mon. p. 173; GEOL. MAG. Vol. X. p. 112).

In one instance (Pl. I. Fig. 1) the head is associated with seven consecutive well-preserved somites or body-segments; in another instance with five segments; the other two examples have portions of segments only in association with the head, but of their identity I feel no doubt on comparison with the others.

The head is somewhat rounded in outline, the sides being compressed and the posterior border slightly incurved. The anterior portion of the head, which is tumid, is without divisions, and is not ornamented save for a minute granulation common to the general surface. The posterior half has a clear straight groove down the centre, and on either side is marked by two lateral curved grooves which subdivide the back of the head into four tumid lobes; the two subcentral ones are the largest and are arched in front so that they overlap the two outer lobes which lie within their lateral concavities.

At each antero-lateral angle of the two subcentral lobes there is a small rounded prominence marked by a corresponding circular pit on the inside of the head. These are no doubt the points of articulation for a pair of simple antennæ, and they are placed just in front of the compound eyes. These occupy the two small elevated lobes at the latero-posterior angles of the head, and are in almost similar relative position as in the head of the modern *Julus*. There are about ten rows of facets in each eye (Plate I. Fig. 3 *o*), and seven or eight facets in each row; the smallest facets being those nearest the centre of the head, and the largest towards the border. Behind the posterior lobes of the head is a simple granulated margin, one millimetre broad, running parallel with its posterior border. Breadth of head 14 mm., length 10 mm.

In addition to a very well-preserved detached head twisted half round, seen in Plate I. Fig. 1 (closely agreeing with that drawn on Plate I. Fig. 3), the same nodule retains the impression and counterpart of seven body-segments united together exposing their dorsal aspect. Each segment consists of a broad, raised, median ridge, bearing two subcentral bases of spines, the spines themselves having been broken off. They are, however, occasionally to be seen in sections of somites, as at the end of Figs. 4 *s*, and in 2 *s*.

This ridge extends to and unites with the lateral border, where it gives origin to a large unequally branched spine, the longest ramus of which measures 10 mm. (in Pl. I. Fig. 1); at the antero-lateral border of each somite there arises a simple pointed spine 4 to 5 mm. long, directed forwards, and a very minute simple spine on the postero-lateral border directed backwards. These larger spines were at least 5 or 6 mm. long, if not more, and they are seen to be hollow. They certainly varied slightly in character and in length in the same individual, as did also the segments upon which they were borne, according to their position in the animal's body.

Occasionally, as in Pl. I. Fig. 7 *s*, the ordinary forked marginal spine is seen to be trifid; but this I am persuaded is due to the single simple spine, which is usually found at its base, occurring rather higher up than usual, and is not a specific character.

The hindmost segment preserved in Fig. 1 measures 15 mm. in

breadth and 6 mm. in length, and one of the anterior segments 12 mm. in breadth and 5 mm. in length.

Another specimen (not drawn) exposes seven body-somites in juxtaposition; the spines are wanting, save one perfect dorsal spine, which is seen attached to the seventh somite, and measures 5 mm. in height. The margin of the tergum of each somite is seen along the right side, and is rather more rounded behind and slightly pointed in front. (See Pl. I. Fig. 13, *ep.*)

The left side is buried in the nodule for about one-third of the surface of the terga. The seven somites together measure 50 mm. long, giving an average length of 7 mm. to each; but the somites are rather more widely separated than usual, so that probably 6 mm. each would be more correct.

Another (Plate I. Fig. 6), from Mr. Beale's collection, exposes five somites, one side displaying the large unequally branched spines, and the small simple antero-lateral spines at their bases, with a trace only of the small latero-posterior spine. On the other side the spines are broken off, showing their hollow shafts, and displaying the lateral border of the tergum of each segment, which is minutely serrated posteriorly. From these specimens I infer that these large spined Myriapods were less round in section than Scudder represents, and that the epimeral portion of each somite projected slightly outwards above its sternum. Length of five somites 35 mm., or averaging 7 mm. each; breadth 18 mm. (exclusive of spines, which would project 9 or 10 mm. beyond this on each side).

This specimen represents a part of the largest example known in England, being 2 mm. wider than Salter's *E. ferox* in the Jermyn Street Museum; but the length would be about the same. In Mr. Beale's specimen the somites are lying in one plane; in Salter's type they are highly curved, and the elevated ridge of each somite has been slightly broken away along its posterior dorsal line. By a misadventure, Figs. 6 and 7, Plate I. have both been drawn with the anterior extremities downwards, the other specimens being all drawn in the contrary direction, with the anterior end upwards.

Perhaps the most instructive specimen in the entire series is one from the late Mr. Henry Johnson's collection, from Coseley, displaying seventeen segments of one individual in the same nodule. The seven anterior somites exhibit their terga and also their branched spines very well (save the first, which is broken), the next succeeding seven somites exhibit a section of their terga, and expose the sterna of five somites seen from within, and the bases of the legs of the left side, and all the legs of seven somites on the right side.

In this specimen the legs, where fully exposed (Pl. I. Fig. 12), are 17 millimetres long; the first two or basal joints which unite with the sternum measure together 3 mm.; the third joint is the longest and widest (length 6 mm. and width $1\frac{1}{2}$ mm.); the fourth is 2 mm. long, the fifth is 3 mm., and the sixth is 3 millimetres.

At the base of each pair of legs, and lying in the median line of the sternum, a pair of minute pores (Pl. I. Fig. 5 *b*) or puncta are seen, which are described by Scudder as "a pair of supposed branchial

supports;" but as each paired sternum is also perforated above the point of articulation for the legs (Pl. I. Fig. 5 *l*) with two spiracles in the form of oblong slits (four to each segment, Pl. I. Fig. 5 *sp.*), agreeing with the two pairs of legs, I fail to see any reason for the assumption that these minute pores, if pores they be, are the basis of gills (see also Pl. I. Fig. 4).

Even admitting that these forms may possibly have been sometimes either voluntarily (or involuntarily) aquatic in habit, yet such a suggestion, unsupported by any evidence in its favour, would hardly warrant one in establishing so anomalous a type as a Dipnoid order of Myriapods breathing both by external gills and internal tracheæ.

This specimen seems rather to favour the notion of a slight diminution in the size of the body-segments towards both extremities of the animal, although we are unable to state with certainty how many more somites are wanting in order to complete the body at either extremity.

In addition to the two specimens showing heads, Mr. Beale's collection has also furnished a single terminal segment, or pygidium, which is associated with a spined body-segment, showing it to belong to the same genus, and probably to the same species. The tail-plate is somewhat pentagonal in form, with two bifid curved spines, one on each lateral border, and four smaller simple spines, two on each side of the median line; the centre, which is transversely ridged, has two obtuse tubercles placed like the body-spines subcentrally; width of tail 6 mm., length 5 mm., length of longest lateral spine 11 mm., length of submedian spines 5 mm.

It is not improbable that this pygidium may have been associated with a form like that on Plate I. Fig. 7, or even Fig. 9; the details of its ornamentation agree with all, and its size with Fig. 7.

So many important points attach to a full consideration of these forms, that I reserve further figures, descriptions and comparisons for my Monograph on the Arthropods of the Coal period, to appear in a forthcoming Memoir of the Palæontographical Society, where I hope to discuss fully the question of species. I may then, possibly, separate Figs. 7 and 9 as distinct, but prefer at present to defer doing so, more illustrations being needed for my task.

Meantime I have to return my best thanks to Mr. C. Beale for the beautiful series of specimens with which he has so kindly entrusted me, and to which I hope to do more ample justice anon.

Before quitting these Carboniferous Myriapods, I desire, however, to draw special attention to a mere fragment of one from the Carboniferous Limestone of Grassington, Yorkshire, where it occurs in association with numerous remains of *Phillipsia Derbiensis* and a *Fenestella*. Only four somites are preserved, and these are evidently spinigerous after the manner of *Euphoberia*; but the spines are longer and more slender, and it does not seem quite certain that any of them were branched (see Plate I. Fig. 10).

I only propose to call attention to the remarkable fact of this form being found, not associated with Ferns and true winged insects, in Clay-ironstone nodules of probable freshwater origin, but in a pure

crystalline limestone full of marine organisms, a most improbable gisement for a Myriapod! The specimen belongs to the Museum of Practical Geology, Jermyn Street, S.W.

EXPLANATION OF PLATE I.

Remains of Spined Myriapods from the Coal-measures.

FIG. 1. *Euphoberia ferox*, Salter, sp. Coal-measures, Sedgley. (Mr. C. Beale's Collection.) Head with seven body-segments. *a*. anterior margin of head. *p*. posterior attached border. *o*. one of the eyes. (Beale Coll.)

,, 2. A detached head of another specimen showing the eyes and also segments with the spines preserved, but much crushed. (Beale Coll.)

,, 3. Another detached head showing the eyes (*o*), the attachment for the simple antennæ (*f*), one of the antennæ (*a*) close to the front of the head.

,, 4. A specimen of *Euphoberia* with 17 somites united in one animal. This specimen shows the legs and the spiracles (*sp*). (Hy. Johnson Coll.)

,, 5. A portion of the sternum with articulations of 4 legs (*l*) and the openings of 4 spiracles (*sp*); also the supposed "basis of branchiæ" (*b*).

,, 6. Another specimen showing 5 somites with lateral bifid spines and small marginal ones attached. (Beale Coll.)

,, 7. Another form, longer and narrower in proportion than Fig. 6, with 5 somites bearing lateral bifid and one trifid spine (possibly a new species?). (Hy. Johnson's Coll.)

,, 8. Terminal segment or 'telson.' (Mr. C. Beale's Coll.)

,, 9. Another and smaller example of *Euphoberia* with 12 connected somites (associated with leaves of *Neuropteris*), bearing one or more trifid spines (possibly a new species)?

,, 10. Fragment consisting of 4 somites bearing slender curved spines. Carboniferous Limestone, Grassington, Yorkshire. (Mus. Pract. Geol.)

,, 11. Ideal section through *Euphoberia ferox*, showing position of simple and bifid spines on tergum (*t*) and the legs and spiracles (*sp*) on the sternum (*s*).

,, 12. Two of the legs drawn separately from Fig. 4.

,, 13. Side view of three segments to show the profile of body-rings with their ridges and the bases of their spines. The lateral margin (*ep*) is seen to be slightly serrated along the posterior border.

Mr. Beale's specimens are all from the Clay-ironstone of the Coal-measures of Sedgley, near Dudley. Mr. Henry Johnson's are all from Coseley, near Dudley.

II.—THE CULM MEASURES OF DEVONSHIRE.

BY W. A. E. USSHER, F.G.S.

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PROBABLY from the great preponderance of interest attaching to the Devonian rocks of North and South Devon the Culm Measure rocks, constituting the great central table land, have been to a certain extent overlooked. The attempt to subdivide them by ascertaining their different lithological characteristics, and observing to what extent these characteristics are peculiar to definite horizons, has seldom been made. We may, in fact, sum up the literature of the subject with one notable exception—the late Prof. J. Phillips in his "Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and W. Somerset"—as bearing upon the position of the series as a whole, or calling attention to some special point of interest.

Phillips, in the work referred to, pointed out the relative position in the series of the most characteristic or important members, such as the limestones, and the cherty beds of the Coddon Hill type. He

also showed that these typical rocks had their equivalents along the southern margin of the great Culm Measure Synclinal.

Phillips gives the following grouping of the Culm Measures in the south part of their range.

Upper or Grit Group of Central Devon.
Upper Shale Group—A mass chiefly of dark shales, carbonaceous grits and shales, the lowest part being the Coddon Hill chert series.
Middle or Calcareous Group—Limestone, mostly black, irregularly bedded, associated with shales, often resting on trap rock and fossiliferous.
Lower Shale Group—Black argillaceous plate, or very laminar shale, not subject to slaty cleavage, and scarcely fossiliferous.

"Following the line of the carbonaceous group of North Devon to the east," says Phillips, p. 194, "it is lost under the superimposed red marls and sandstones; these range nearly north and south across the general strike of the carbonaceous group and conceal it . . . On the west the carbonaceous group occupies the coast from Fremington nearly to Tintagel, and on the south it follows a line much bent by the effect of the protruding granitic masses, especially of Dartmoor. In the centre of this great district no limestone occurs, and there are no other fossils than obscure marks of plants or mere carbonaceous stains; but on the southern border the limestone bands reappear almost exactly as on the northern side with similar mineral characters and accompaniments, and similar or identical organic remains; for example, at Trescott near Launceston, Lew Trenchard, Bridestow, and Okehampton."

Beds of Anthracite occur in the Culm Measures of North Devon in the neighbourhood of Chittlehampton, Tawstock, Abbotsham, and Alverdiscot; they are alluded to by Polwhele,[1] by Vancouver,[2] by Lysons,[3] by Sedgwick and Murchison,[4] and De la Beche;[5] the latter says: "Anthracite or Culm occurs in a few beds of very variable thickness between Greenacliff on the coast west from Bideford and Hawkridge Wood near Chittlehampton."

"Sufficient Anthracite was at one time raised near Greenacliff, in Barnstaple Bay, to burn with the limestone brought there from South Wales."

Mr. T. M. Hall (Trans. Dev. Assoc. for 1875), in a paper entitled "Notes on the Anthracite Beds of North Devon," says: "The widest culmiferous band is nearly 18 feet in width, but several smaller strings of the same material traverse the slates and shales.

"At Bideford, a few yards north of the Railway Station, may be seen the black shales forming the outcrop of the veins which, until a very recent period, were worked to a considerable extent. . . . About a mile east of this spot the present works, consisting of a shaft and level adit, are still carried on for the purpose of obtaining the softer varieties of Anthracite, which when ground to powder are sold as a pigment under the name of Bideford Black."

[1] History of Devonshire, p. 55 (1797).
[2] General View of the Agriculture of the County of Devon, p. 266 (1808).
[3] Magna Britannia Devon (1822), p. 266.
[4] On the Physical Structure of Devonshire (1840).
[5] Report on Geol. Corn. Devon, etc. (1839), p. 513.

Mr. Hall gives the following list of fossil plants obtained from the North Devon Culm Measures:—

Asterophyllites foliosa.
„ *galioides.*
„ *longifolia.*
Bowmanites (fruit of Calamite).
Calamites arenaceus ?
„ *cannæformis.*
„ *nodosus ?*
„ *Steinhauerii.*
„ *undulatus.*
Cyperites bicarinata.
Lepidodendron.
Lepidophyllum intermedium.
Neuropteris cordata.
„ *gigantea.*
Neuropteris heterophylla.
„ *Loshii.*
Pecopteris lonchitica.
„ *muricata.*
„ *Serlii.*
Poacites cocoina.
Sigillaria.
Sphenopteris acuta.
„ *latifolia.*
Spenophyllum sp. (?).
Sternbergia.
Stigmaria ficoides.
A single shell of the genus *Anthracosia* also found near Bideford.

Mr. H. B. Woodward informs me that *Cœlacanthus* has been found at Instow.

In Lower Culm Measure Shales at Waddon Barton near Chudleigh, ? Mr. Reid obtained four species of *Phillipsia, Goniatites sphæricus, Orthoceras striolatum, Posidonomya Becheri, Avicula lepida, Chonetes deflexa, Spirifera Urii*, etc.[1]

In a survey of the Triassic rocks of Devon extending over several years, I had ample opportunities of observing the Culm Measures on their borders; but it was not till the years 1876 and 1877 that I had the opportunity of studying the Culm Measure area in a less desultory manner, my researches being confined to the districts east of a line between Hartland Point and Okehampton.

In this area I discovered that the Culm Measures were broadly divisible into three groups, which, however, owing to the passage of one group into another, and to local intercalations, and to a great extent to the innumerable flexures of the beds, cannot be separated by hard and fast lines. Whether such a separation could be effected on a 6-inch scale map I cannot say, but it would entail an infinite amount of labour. The following is the general succession:—

Upper—Eggesford type.—Hard rather thick, even-bedded grey grits, slaty beds and shales.

Middle—Morchard type.—Thick-bedded grey, greenish, and reddish sandy grits, associated with marly splitting shales, irregular grits, slates, and shales.

Lower ... ... { Dark grey shales, with grit beds, seldom thick, and generally even, slaty, and splintery shales (type St. Davids Exeter). Even-bedded cherty shales and grits (of Coddon Hill type). Limestones and dark-grey shales.

In general facies these groups are quite distinct, thus the even bedding and regular appearance of the fine-grained grey grits of Eggesford is very distinct from the irregularly associated grits and shales of the underlying beds, whilst the massive bedded sandstones and marly shales which occur in them about Zeal Monachorum, and other places on the north of the Crediton Valley, give the Middle Series or Morchard Bishop type of beds a very different general

[1] For a further list of the Waddon Barton Fossils, including the Trilobites, described by me, see GEOL. MAG. Decade III. Vol. I. 1884, p. 539.—H. W.

aspect from the lower series, although splintery shales (of the St. Davids Exeter type) appear to be interstratified with them in places.

Upon the one-inch map it is perfectly impossible to work out the structure except in a broadly general way; there is no room on a small scale map to indicate the numerous folds, and it is quite impossible to ascertain the effect and magnitude of the faults.

The great Culm Measure Synclinal is not a simple curve, the beds troughed by it being crenulated, so to speak, into an infinity of small folds, and in this crinkling process they have no doubt been forced to accommodate themselves to an area so much smaller than that of their pristine extent, that we may suppose overthrust faults very likely to have occurred, and, coupled with natural impersistence of lithological horizons, lenticular association of grit and shale masses and structural peculiarities such as may frequently be found in the Middle, and sometimes in the Lower Culm Measures; these considerations tend not a little to obscure the relations of the beds.

Lower Culm Measures.—On their northern outcrop the beds forming this series occupy a very much narrower tract than that to the south. Their northern outcrop is about two to three miles in breadth; their southern outcrop varies very considerably, its breadth from Dartmoor northward through Okehampton being about five miles, whilst on the east of Dartmoor it is about 15 miles, and about the same on the west of Dartmoor through Lidford; but it must be remembered that this estimate in the southern part of the area is necessarily based on the old geological Map, and that both in northern and southern districts the Lower Culm Measures may occur far beyond the limits assigned to them, through repetitions by faults or anticlinal axes in the areas occupied by the Middle Culm Measures.

The Lower Culm Measures, owing to the occurrence of limestones and of the remarkable buff and grey shales and cherty grits of the Coddon Hill type in them, and to their connection with the Upper Devonian beds, naturally excited more interest and attention than the other members of the series, except the Anthracite beds of the Middle Culm Measures of the north; but I do not think, at least in the northern area, that they can be subdivided in anything like persistent groups. If, for instance, we take the faulted and much-flexured limestone patches of West Leigh,[1] Hockworthy, Whipcoats, and Kitton Barton, it is not difficult to determine their boundaries; but to establish their connection in a continuous series is by no means easy. Furthermore, when we follow their horizon westward, although we can have no hesitation in regarding the limestones of Bampton and of Ven near Barnstaple, as the same series, the entire absence of continuity for such considerable distances forbids the hypothesis of a persistent calcareous horizon, which could only be proved by systems of faults of which we could not hope to obtain sufficient proof. From their local development, and very partial occurrence, both in the northern and southern areas, I regard the limestones as lenticular masses in the shales and grits.

[1] *Vide* Trans. Dev. Assoc. for 1878 and 1879, Fossils in Culm Measures Limestone, etc., by Rev. W. Downes.

Again, the peculiar baked appearance of the Coddon Hill beds is more or less local, although appearing at such wide intervals as the Northern and Southern Culm Measure areas, wherein their characteristic appearance was severally noticed by Phillips; and the limestones may be said to occur in them, the reddish even Goniatite shales of the West Leigh area belonging to this group.

Referring to the Coddon Hill beds, pp. 189, 190, Phillips says:—"The beds, which in this range overlie the shales and limestones of Swimbridge and Venn, are a whitish or grey or black chert in thin striped beds. . . . With these lie white arenaceous and argillaceous layers, mostly very soft, and sometimes cleavable, other parts show black and reddish shales. In these laminated beds lie Goniatites, Orthoceratites, Terebratulæ, and Posidoniæ. The debitumenized condition of these white shales parallel to the black bituminous shales of Swimbridge is remarkable; and it is a fact repeated not only on the Northern range near Bampton, but also on the southern range near Launceston and Lew Trenchard. In a quarry on this range near Tawstock, Major Harding found *Turbinolopsis pauciradialis*" (*Petraia celtica*).

To take one or two examples from many furnished by my notes: The Venn limestones are exposed in two adjacent quarries; in the smaller one they are very much disturbed, being probably affected by two faults; they appear to overlie beds of the Coddon Hill type. In the larger quarry even-bedded dark grey limestones dip 35° W.; at 60°, they are interleaved in places by shaly parting. One of the beds is covered on its surface with impressions of *Posidonomya* (*Posidonia*) *lateralis*, and less frequently *P. Becheri* and *P. tuberculata*.

Near Eastcombe, west of Tawstock, thin beds of fine grit and thick shale of whitish buff and dark grey colours, split up by numerous even joints into small angular pieces, are quarried for "gravel." The joints, as is usual in beds of the Coddon Hill type, are local contraction-cracks of individual beds.

The flexures and contortions of this series are too numerous to furnish any generalized observation as to the relations of the beds, and space fails me to enter into local details.

In the south of the area, notwithstanding the local repetition of the calcareous horizon, and of beds equivalent to the Coddon Hill series, there is some difference in the general characters of the Lower Culm Measures; thus slaty grey shales which, from their typical exposure on St. David's Hill, Exeter, I have called splintery shales of the St. David's type, are by no means uncommon in them, also beds of a nodular or concretionary character; the grits vary from thin and even, to rather thick irregular beds.

Phillips thus describes the Lew Trenchard section: "Argillaceous and arenaceous laminar beds, white or coloured by oxide of manganese, which correspond to those of Coddon Hill in North Devon, contain *Calamites, Asterophyllites, Neuropteris*, and a *Goniatite*, . . . below are quarries of black limestone" with "shaly partings rich in *Posidoniæ*" in the upper part. No Goniatites found in the limestone. Phillips points out the occasional presence of oolitic structure in the limestones of this series.

The junction between the Lower Culm Measures and Upper Devonian slates of North Devon is very seldom visible, but there are cases, as in the railway cutting near Dulverton Station, where we pass from shales distinctly belonging to the Culm Measures to shales lithologically indistinguishable from them in which *Petraia celtica* was obtained.

Phillips says, p. 189, "The exact circumstances of the passage from the upper part of the Pilton group to the lower part of the Carbonaceous group . . . are scarcely anywhere completely seen in North Devon. There is usually a longitudinal valley on the line of junction which obscures the phenomena. Fremington Pill is perhaps the best locality for observation of this passage." As to the junction between Culm Measures and Devonian in South Devon, it is one of the questions of the future. Phillips points out appearances of unconformity between the Petherwin beds (Upper Devonian) and Lower Culm Measures at Landlake, south of Launceston, *op. cit.* p. 196, and I do not think that the comparative absence of the Upper Devonian strata has been accounted for in South Devon. On the broad questions of correlation many plausible suggestions have been made; but if the Pilton beds are unquestionably representative of the Lower Carboniferous Slate of Ireland, what becomes of that representation in South Devon? Is it possible that the Upper Devonian Slate series is in South Devon represented by Lower Culm Measures, through that Division attaining a much greater thickness in the southern area? It may be that the greater extension of Lower Culm Measures in the southern area is due to low dips or more constant repetition by faults and flexures, see F. Rutley "On the Schistose Volcanic Rocks of Dartmoor," Q. J. G. S. vol. xxxvi. p. 287. 1880, and Harvey B. Holl, Q. J. G. S., vol. xxiv. p. 407, 1868.

Middle Culm Measures.—These rocks occupy the coast from Westward Ho to Portledge Mouth. The breadth of their outcrop from Northam to Wear Giffard in the longitude of Bideford is about four miles; their southern outcrop from the Triassic valley of Crediton northward embracing Morchard Bishop, Iddesleigh, Meeth and Petrockstow, is from 4 to 5 miles in breadth.

Fig. 1.

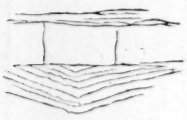
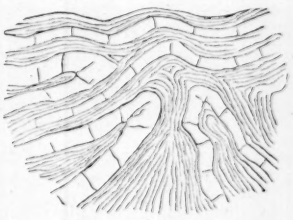


Fig. 2.



The Middle Culm Measures are a very variable series, their special characteristics are rather coarse sandstones, which, near Zeal Monachorum and other places in their southern outcrop, occur in beds about five feet thick, and are associated with marly splitting shales

or red finely micaceous mudstones. In the north part of the area the marly shales are less frequent, and hard thick-bedded whitish sandstones and siliceous grits occur. Through the very irregular association of the slates, shales and grits which form the major portion of this series, many structural peculiarities are presented, especially in the very irregular manner in which the constituent beds have yielded to the strains to which they have been more than once subjected since their deposition. The accompanying diagram represents a case of contortion in the cliff near Westcot, the occurrence is presented in a space of about seven square feet. Near it we have a bed of greenish grey grit lying across the edges of a trough in the subjacent shales (Fig 2).

The coast from Portledge Mouth towards Westward Ho shows successively reddish-brown and lilac grits, grey grits, blackish shales and grey grits, dark grey shales and slaty beds, hard grey grit forming an anticlinal, shales with thin beds of grit, massive grey grits and grey shales. It was from this part of the coast that the diagrams were taken,—irregular concretionary grits on a thick bed of whitish grit at about 85 chains from Portledge Mouth, upon thick beds of grey sandy grit broken by irregular joints, upon massive beds of grey quartz-veined grit associated with dark grey shales forming a fine anticlinal, hard coarse grey grits and dark grey shales flaking off in splintery fragments in places, under these beds dark shales with thin even beds of grit, possibly Lower Culm Measures, come on, they appear to be faulted against massive beds of grey grit, one bed being eight feet in thickness. The above represents the coast section for more than a mile and a half; in that space we have about 18 well-marked anticlinal and synclinal curves, not to mention numerous lesser flexures, and two appearances of fault.

Space fails me to particularize the continuation of the coast-section in the direction of Westward Ho. From Peppercombe to Clovelly the coast is formed for the most part of beds of the Eggesford type, Upper Culm Measures.

From Clovelly to Hartland Point the coast has not been observed, but from its projection it would appear to consist of Middle Culm Measures, of which the following is the downward succession at Hartland Point: Light greenish grit; on dark grey slates and shales with beds of greenish grit; thick bed of brown grit; reddish schistose beds and shaly mudstones splitting in sub-cuboidal pieces like marl, associated with thin beds of grit; thick beds of hard lilac grit with shale; dark grey shale; even-bedded quartz-veined grey grits; dark grey indurated shale; hard grits with dark grey shale partings; bed of grey quartz-veined grit; dark grey shales and schistose beds. The beds are contorted.

The Eggesford grits or Upper Culm Measures form a much more regular and less variable series than the beds hitherto described; they form a band of six or seven miles in breadth. They are well exposed in the railway cuttings near Eggesford, in the Torridge Valley about Great Torrington and in the coast near Clovelly. It is impossible on the one-inch scale to convey any idea of the many

flexures in them, every section almost, of a few yards in length, affording an indication of disturbance.

Between Clovelly and Portledge Mouth the Upper Culm Measures consist of grey, lilac-grey and reddish thick-bedded even grits, with interstratification of dark grey shale. The even-bedded character of this series renders the flexures in the cliffs very apparent, especially when dark grey shale bands are affected by them, as at 31 chains from Clovelly Pier where sharp inverted curves are shown, V shaped flexures are visible about 14 chains from the Pier, and from 18 to 22 chains from the Pier the beds are contorted and faulted. At about 70 chains from Clovelly beautiful examples of marine tunnelling are afforded by the Black Church rock, in which two tunnels have been excavated along the bedding, and by a neighbouring reef in which the sea attacked the opposing strike surface, the tunnel being roofed by a massive bed dipping landward.

Fig. 3.

To enter more fully into the many inverted and ordinary curves exposed in this interesting coast would be beyond the purport of this paper. I have not attempted to give a digest of the numerous notes I have made of the Culm Measure area, nor do I think it would be possible to do so; but I trust that I may have succeeded in directing attention to a large district practically unknown to geologists, and in showing that, in spite of the confusing complexity of detail, it is possible to obtain something like a definite sequence. To make out the structure thoroughly would require years of patient labour on the 6 inch scale, and is in no sense feasible in holiday rambles; but there are curious structural phenomena which would amply repay the labours of the casual visitor.

III.—Notes on "Cone-in-Cone" Structure.

By W. S. Gresley, F.G.S.

In Decade III. Vol. II. of the Geological Magazine, for 1885, at page 283, an abstract of a paper on "Cone-in-Cone" by Mr. John Young, F.G.S., of Glasgow, was given. The author of this interesting paper has kindly presented the writer with a copy of it, to which, since it was read in Glasgow last year, has been added some additional remarks, together with two very beautiful plates, by 'photogravure,' in illustration of some of his typical Scottish specimens.

The result of Mr. Young's labours in this connection have warranted him in arriving at the following conclusion respecting the origin and formation of cone-in-cone structure, which, briefly stated, is this:—That the formation is due to the "upward and successive escape of gases generated in the lower portion of the stratum in which the structure is found, probably by the decay of

organic matter in the deposit whilst still in the process of formation and in a soft, sedimentary condition; each ebullition of gas being marked by a new or successive layer of sediment within each cone." "That the cones, large and small, have their apices invariably directed towards the lower portion of the stratum."

As, in the course of the last year or two (due chiefly to the occurrence of some interesting examples of cone-in-cone in the breccias of the Permian? series in Leicestershire, see Q. J. G. S. vol. xli. Proceedings, page 109, and the "Midland Naturalist," vol. ix. No. 97 [new series]), the writer has given some attention to this interesting rock-structure, his observations in the field and elsewhere have brought to his knowledge several important facts, and such as have reluctantly prevented him from accepting Mr. Young's theory.

Although Mr. Young has gone very fully into the question, he does not appear to have noticed one or two important points often seen in cone-in-cone structure, which I will now endeavour to describe.

Fig. 1

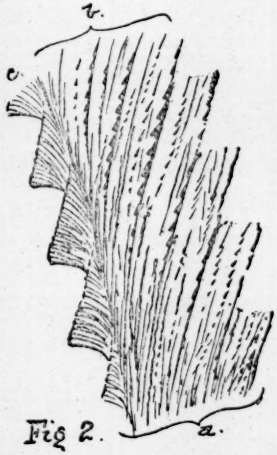


Fig 2.

½ nat. size. 4 times nat. size.

(*a*) In the case of large, strong, well-developed cones, often four or five inches in length (see Fig. 1), and generally composed of compact siliceo-ferruginous sandstone in the Coal-measures, which I will call 'master cones' because they seem to cut out the feebly developed ones in their upward expanding growth; the walls, or substance of the cones, or conical-shaped cups or portions of such (for whole hollow cones are rarely met with), often as much as a quarter of an inch in thickness between the usual concentric layers of corrugations more or less filled with clayey material, are themselves composed of cone-in-cone formation (also possessing their clay-filled serrations); the bases of the cones abutting upwards upon the clay wrinkles which separate each great cone or part of a cone. A reference to

Fig. 2 will probably better explain what is intended to be noticed above. It represents a portion of a vertical section of one of the master cones enlarged about four times. The specimen is from a bed of clay-ironstone occurring above the fire-clays of the Western division of the Leicestershire Coal-field — a horizon which has furnished the writer with more than one illustration of the way in which cone-in-cone structure occurs.

But further, I would point out that the concentric serrations between the cones, and shown as adhering to the exterior surface of one of them at *c*, Fig. 2, are also composed of scaly or semi-cone-in-cone structure. This, though of minute development, can readily be detected with a pocket lens, especially upon partially weathered samples. The bases of these tiny flakes seem to terminate against the serrations of the master cones, and upon the sides of the cone-structure forming their walls (see Fig. 2). In short, this specimen (and doubtless it is a typical one) appears to be wholly built up of 'cone-in-cone,' of at least three separate and distinct developments, *a*, *b*, and *c*. For this curious three-fold structure I fail to see how the ebullition-of-gases theory can satisfactorily account.

With reference to the question of cone-in-cone found upon the under as well as the upper surface of a stratum or a concretionary mass, Mr. Young would have us believe that when this does occur it has probably been due to the shrinkage of the mass, such contraction having actually carried the coned surface round to the underside. I think the following instances of reversed or double cone-in-cone at once upset his theory.

(*b*) In a stratum of blue shale or 'bind' at the village of Donisthorpe in the Leicestershire Coal-field, occur some large concretionary masses—often several tons in weight—of hard and compact fine-grained siliceo-ferruginous sandstone, locally called 'cank,' whose upper and lower surfaces are often largely covered with cone-in-cone formation. That upon the under surface, however, is always the most feebly developed. Now, as the coned surfaces are always most strongly formed in the centre of the mass, or, in other words, as the

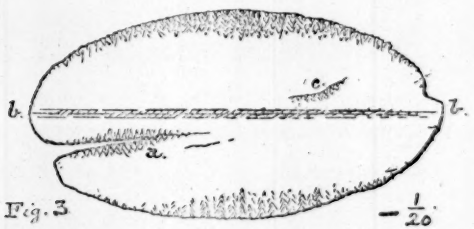


Fig. 3 — $\frac{1}{20}$.

edges towards *b b* (see Fig. 3, which represents a transverse section) are almost devoid of cone structure, it is at once apparent that the cones upon the under side cannot have been brought into their present position by any known process of shrinkage or curling up, or downwards, of the nodules. Besides, in one instance, we have at *a*,

a double cone-in-cone development on the surfaces of a large crack or cavity in the side of the specimen; whilst at *c*, in the interior of the same nodule, occurs a small and rather feeble development of the same structure, in no way connected with the top and bottom cone-in-cone layers. Again, as the band marked *b b*, which is a layer of three or four inches of argillaceous ironstone, is crowded with well-preserved leaflets of *Neuropteris gigantea*, surely these organic remains must have greatly suffered had contraction of the mass taken place to any extent, which is not the case.

(*c*) Very good hand-samples of whole disc-shaped clay-ironstone nodules, exhibiting on both flat surfaces well-formed cone-in-cone structure, are preserved in the Geological Museum of Owens College, Manchester, and here again we find that this structure is much more strongly developed on one side than on the other, and that the coned surfaces are confined to the central parts of the nodules, as shown in Fig. 3, which is roughly half the size of the Manchester specimens. As these nodules were not labelled, I cannot give their locality, etc.

(*d*) In the Museum of the Yorkshire College of Science, Leeds, there is a small specimen of earthy limestone from the Wealden beds, Brixton Bay, Isle of Wight, upon whose upper and lower surfaces cone-in-cone formation is seen—very minute upon the underside—the upper one commencing in contact with a layer of fossil bivalve shells whose uneven surface corresponds with that of the apices of the cones.

(*e*) I have quite recently noticed in the shale "baring" of the fire-clay opencast workings in the Leicestershire Coal-field singular nodular masses of hard flinty fine-grained stone (a worthless variety of clay-ironstone), one of which is shown in cross-section in Fig. 4. Upon the surface of this specimen the cone-structure has the appearance of having been subjected to considerable shrinkage, as the cones or rather wedge-shaped scales of cone-in-cone structure, occur in curious wrinkles or ridges upon the general surface of the stone. As these singular examples were not seen *in situ*, I cannot say which sides were uppermost in the shale.

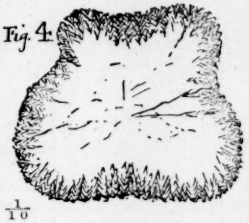


Fig. 4. $\frac{1}{10}$

(*f*) Again, occurring in the same stratum are some large concretionary somewhat tabular-shaped masses of the same kind of rock as that last noticed, and having a kind of clay-ironstone band running through their centres (see Fig. 5). These nodules are sometimes several tons in weight. Now, forming the entire upper *and lower* portions of these singular stones are cone-in-cone structures as shown in the sketch; and occupying zones lying between the cone-in-cone portions and the rather sharp edges or peripheries of the masses, both upon upper *and lower* surfaces, are formations of innumerable little spheres or spherulitic concretionary masses, and, as it were, grown together,—very perfect and distinct upon the surface, but rapidly dying out towards the interior of the stone, and apparently grading

into the cone-in-cone formation on the one hand and disappearing in the opposite direction, namely :—towards the periphery of the nodule (see Fig. 5).

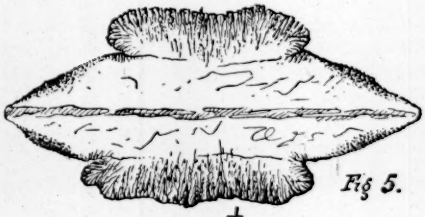


Fig 5. $\frac{1}{10}$.

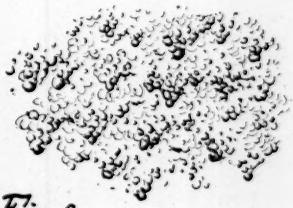


Fig 6. $\frac{1}{20}$.

A peculiarity in the appearance or arrangement of this spherulitic structure is that the surface of it often takes a beautiful wavy or fantastic stalagmitic form, giving the idea that the substance of the structure was in a semi-fluid condition during formation of the botryoidal structure. The aspect is not altogether unlike a number of flat bunches of very small grapes, disposed in more or less regular rows or terraces one above another (see Fig. 6). The globules or spheres forming the apices or lowest points of these little wavy ridges are always the largest or most perfectly developed of the individual groups or bunches. These tiny spheres contain a considerable percentage of lime, as do the cone-in-cone masses which are encircled by them.

With respect to the mineral constituents of cone-in-cone rock, Mr. Young seems to hold that calcareous matter was essential to its existence. As many of my specimens are not affected by the acid test, the lime, if originally present, has been since removed.

It may be interesting to remark here, that cone-in-cone structure occurs in the Upper Cambrian rocks—the Skiddaw slates—near Shap. Were it necessary, I could instance other interesting examples of cone formation, but from what has been said it will be obvious that, notwithstanding my admission of Mr. Young's perseverance and care in having worked out so much and given a very reasonable explanation of cone-in-cone, which, had it not been for the discovery of the double and the complicated instances, I should certainly have accepted as the probable correct one, I am compelled to discard it as not being sufficient to account for all the observed facts.

It is exceedingly improbable that this kind of cone-in-cone structure can have been formed in one way as regards the upper layers of it; and in another way as to those found with their bases pointing downwards. I myself have no explanation to advance. The structures observed are, however, very complex, they seem to deserve a closer examination than they have yet been subjected to, not in the field only, but in the laboratory and also microscopically.

Fig. 1, natural size. Vertical section of portion of three 'master' cones.

Fig. 2, × 4. Enlarged view of part of a 'master' cone. *a*. showing the cone structure in its walls. *b*. and *c*. the semi-cone formation of the clay serrations on the back of the 'master' cone.

Fig. 3, one-twentieth natural size. Transverse section of a large concretionary mass of compact siliceous ironstone, exhibiting cone-in-cone structure upon both upper and under surfaces, as well as in the interior of the mass, at *a* and *c*. The band *b*, *b*, is clay ironstone crowded with leaflets of *Neuropteris gigantea*.

Fig. 4, one-tenth natural size. Transverse section of a nodule of compact siliceous ironstone, entirely coated with cone-in-cone structure.

Fig. 5, one-tenth natural size. Transverse section of a large concretionary mass of close-grained ferruginous sandstone exhibiting cone-in-cone structure upon upper and under surfaces, and also a peculiar double arrangement of a spherulitic formation surrounding the cone-in-cone areas.

Fig. 6, one-twentieth natural size. Shows the appearance, on the surface of nodule in Fig. 5, of the spherulitic structures occupying the areas surrounding the cone-in-cone masses.

IV.—On a Diamantiferous Peridotite, and the Genesis of the Diamond.

By Prof. H. Carvill Lewis, M.A., F.G.S.

(Abstract of a Paper read at the Birmingham Meeting of the British Association for the Advancement of Science, September, 1886.)

THE discovery of diamonds at Kimberley, South Africa, has proved to be a matter, not only of commercial, but of much geological interest. The conditions under which diamonds here occur are unlike those of any other known locality, and are worthy of special attention.

The first diamond found in South Africa was in 1867, when a large diamond was picked out of a lot of rolled pebbles gathered in the Orange river. This led to the "river diggings" on the Orange and Vaal rivers, which continue to the present time.

In 1870, at which time some ten thousand persons had gathered along the banks of the Vaal, the news came of the discovery of diamonds at a point some fifteen miles away from the river, where the town of Kimberley now stands. These were the so-called "dry diggings," at first thought to be alluvial deposits, but now proved to be volcanic pipes of a highly interesting character. Four of these pipes or necks, all rich in diamonds, and of similar geological structure, were found close together. They have been proved to go down vertically to an unknown depth, penetrating the surrounding strata.

The diamond-bearing material at first excavated was a crumbling yellowish earth, which at a depth of about 50 feet became harder and darker, finally acquiring a slaty blue or dark green colour and a greasy feel, resembling certain varieties of serpentine. This is the well-known "blue ground" of the diamond miners.

It is exposed to the sun for a short time, when it readily disintegrates, and is then washed for its diamonds. This "blue ground" has now been penetrated to a depth of 600 feet, and is found to become harder and more rock-like as the depth increases.

Quite recently, both in the Kimberley and De Beers mines, the remarkable rock has been reached, which forms the subject of the present paper.

The geological structure of the district and the mode of occurrence of the diamond has been well described by several observers. As Griesbach, Stow, Shaw, Rupert Jones, and others have shown, the diamond-bearing pipes penetrate carbonaceous strata of Triassic age, which are known as the Karoo formation.

The Karoo beds contain numerous interstratified sheets of dolerite and melaphyre, also of Triassic age, and the whole reposes upon ancient mica-schists and granites. The careful investigations of Mr. E. J. Dunn demonstrate that the diamond-bearing pipes inclose fragments of all these rocks, which fragments show signs of alteration by heat. Where the pipes adjoin the Karoo shales, the latter are bent sharply upwards, and the evidence is complete that the diamond-bearing rock is of volcanic origin, and of Post-Triassic age.

The diamonds in each of the four pipes have distinctive characters of their own, and are remarkable for the sharpness of their crystalline form (octahedrons and dodecahedrons), and for the absence of any signs of attrition. These facts, taken in connection with the "blue ground," indicate, as Mr. Dunn has pointed out, that the latter is the original matrix of the diamond.

Maskelyne and Flight have studied the microscopical and chemical characters of the "blue ground," and have shown that it is a serpentinic substance containing bronzite, ilmenite, garnet, diallage, and "vaalite" (an altered mica), and is probably an altered igneous rock, the decomposed character of the material examined preventing exact determination of its nature. They showed that the diamonds were marked by etch figures, analogous to those which Prof. Gustav Rose had produced by the incipient combustion of diamonds, and that the "blue ground" was essentially a silicate of magnesium impregnated with carbonates.

The "blue ground" often contains such numerous fragments of carbonaceous shale as to resemble a breccia. Recent excavations have shown that large quantities of this shale surround the mines, and that they are so highly carbonaceous as to be combustible, smouldering for long periods when accidentally fired. Mr. Paterson states that it is at the outer portions of the pipes where the "blue ground" is most heavily charged with carbonaceous shale, that there is the richest yield of diamonds.

Mr. Dunn regards the "blue ground" as a decomposed gabbro, while Mr. Hudleston, Prof. Rupert Jones, and Mr. Davies regard it as a sort of volcanic mud. Mr. Hudleston considers that the action was hydrothermal rather than igneous, the diamonds being the result of the contact of steam and magnesian mud under pressure upon the carbonaceous shales, and compares the rock to a "boiled plum-pudding."

The earlier theories as to the origin of the diamond have, in the light of new facts, quite given way to the theory that the diamonds were formed in the matrix in which they lie, and that the matrix is in some way of volcanic origin, either in the form of mud, ashes, or lava.

The exact nature of this matrix becomes, therefore, a matter of great interest. The rocks now to be described are from the deeper portions of the De Beers mine, and were obtained through the courtesy of Mr. Hedley. They are quite fresh, and less decomposed than any previously examined. Two varieties occur, the one diamantiferous, the other free from diamonds, and the lithological distinction between them is suggestive. The diamantiferous variety is crowded with included

fragments of carbonaceous shale, while the non-diamantiferous variety is apparently free from all inclusions, and is a typical volcanic rock.

Both are dark, heavy, basic rocks, composed essentially of olivine, and belong to the group of peridotites. Both are of similar structure and composition, differing only in the presence of inclusions. The rock consists mainly of olivine crystals lying porphyritically in a serpentinic ground-mass.

The olivine is remarkably fresh, and occurs in crystals which are generally rounded by subsequent corrosion. The principal accessory minerals are biotite and enstatite. The biotite is in crystals, often more or less rounded, and sometimes surrounded by a thin black rim, due to corrosion. Similar black rims surround biotite in many basalts. The biotite crystals are usually twinned according to the base. The enstatite is clear and non-pleochroic. Garnet and ilmenite also occur, the former sometimes surrounded by biotite, and the latter often partly altered to leucoxene. All these minerals lie in the serpentinic base, originally olivine. This rock appears to differ from any heretofore known, and may be described as a saxonite porphyry in which the base is not holocrystalline.

The diamond-bearing portions often contain so many inclusions of shale as to resemble a breccia, and thus the lava passes by degrees into tuff or volcanic ash, which is also rich in diamonds, and is more readily decomposable than the denser lava.

It seems evident that the diamond-bearing pipes are true volcanic necks, composed of a very basic lava associated with a volcanic breccia and with tuff, and that the diamonds are secondary minerals produced by the reaction of this lava, with heat and pressure, on the carbonaceous shales in contact with and enveloped by it.

The researches of Zirkel, Bonney, Judd, and others, have brought to light many eruptive peridotites, and Daubree has produced artificially one variety (lherzolite) by dry fusion, but this appears to be the first clear case of a peridotite volcano with peridotite ash.

Perhaps an analogous case is in Elliott County, Kentucky, where Mr. J. S. Diller has recently described an eruptive peridotite which contains the same accessory minerals as the peridotite of Kimberley, and also penetrates and incloses fragments of carboniferous shale, thus suggesting interesting possibilities.[1]

V.—Note on a Bed of Red Chalk in the Lower Chalk of Suffolk.

(A paper read before the British Association, Birmingham.)

By A. J. Jukes-Browne, B.A., F.G.S.

THE section exposing this stratum was discovered during an excursion made last June by Mr. W. Hill, F.G.S., and the author. It occurs in a quarry near West Row Ferry, about two miles west of Mildenhall;

[1] Since this paper was read, additional evidence that diamonds originate by the action of peridotites on carbonaceous rocks has been collected from many localities. The most instructive examples are from New South Wales, where the diamond gravels lie near the contact of basalts or serpentine with Carboniferous rocks, the serpentine here being an altered olivine enstatite rock. At the Bingera diamond-field a mass of eruptive serpentine is almost surrounded by Carboniferous rocks containing coal-seams. In Western America, also, the diamantiferous gravels are near higher ground, where serpentines and carbonaceous rocks occur together. Possibly a clue may be thus afforded for more systematic search.

here a band of red marly chalk is seen near the entrance, dipping westward at a low angle, but soon becoming horizontal and running along the whole face of the quarry, till it is cut off by a fault, which brings up lower beds on the southern side.

The complete section at the deepest part of the pit, not far from the entrance, is as follows:—

	Feet.
Soil and rubble of yellowish chalk	4
Pink marly chalk, weathering into yellow rubble towards the outcrop	3
Hard nodular grey chalk	2½
Grey shaly chalk	2
Very hard grey nodular and gritty chalk, containing large *Ammonites, Belemnitella plena, and Terebratula semiglobosa*	1
Thin-bedded whitish chalk (*O. vesicularis*)	2½
Hard greyish chalk	2
Softer thin-bedded chalk (*Holaster subglobosus*)	6
Hard lumpy yellowish rock	0½
	23½

At the western end of the pit, where the red band is further from the surface, the following is the section exposed:—

	Feet.
Chalky soil	1
Rough yellowish gritty chalk	4
Red marly chalk, brick-red at the top, pink below, and passing down into grey marly chalk with hard lumps	5
Hard grey rocky and nodular chalk	2
Soft grey shaly chalk, seen for	1
	13

The red chalk breaks into small angular blocks, the edges of which are pinkish white, and all the joint-planes are bordered by whitish bands, about a third of an inch thick; facts which seem to indicate that the percolation of water from the surface has effected a certain amount of decoloration, and that the whole was originally of one uniform colour, darkest at the top, and becoming lighter in tint towards the base.

With regard to the stratigraphical position of these beds, we ascertained that the quarry lies between the outcrops of the Totternhoe Stone and the Melbourn Rock, and is opened in a shallow synclinal trough, so that there must be an anticlinal to the east of the pit and a second outcrop of the red chalk with an easterly dip along a line nearer to Mildenhall, but of this no indication was found. The Totternhoe Stone is found at Isleham, and traces of it occur near West Row, about three-quarters of a mile N.W. of the "red chalk quarry"; the Melbourn Rock is seen between Worlington and Mildenhall, and its outcrop appears to run round Mildenhall at a distance of about a mile and a half from West Row Ferry. *Holaster subglobosus* is found in the lower part of the section at West Row, and the occurrence of typical *Belemnitella plena* points to a high horizon in that zone; the existence of this Belemnite here is indeed an interesting and noteworthy fact, for the typical forms have never yet been found in Suffolk or Cambridge, except at the very summit of the Lower Chalk, From the red chalk itself we obtained no fossils. It is clear, therefore, that the horizon of the red band is about the centre of the zone of

Holaster subglobosus, and at least 100 feet above the base of the Chalk Marl; and, further, that it has no connection whatever with the red rock which forms the base of the Chalk at Hunstanton and in Lincolnshire.

It is well known, however, that the Lower Chalk of Lincolnshire contains two other bands of red chalk, and the author's examination of this district for the Geological Survey enables him to compare the Suffolk and Lincolnshire sections in detail. The following account of the Lincolnshire beds is given with the permission of the Director-General, and in anticipation of the Explanation of the Survey Map (Sheet 84), which is now in the press.

In Lincolnshire, as at Hunstanton, the red (Hunstanton) rock forms the basement bed of the Chalk, and is overlain by four or five feet of hard grey sandy chalk (Inoceramus beds). These are succeeded by about 70 feet of grey chalk with many layers of hard nodular rocky chalk, and including two bands of pink chalk, one (the lower) being in some places of a decided red colour, while the upper band is generally of a yellowish pink tint. The lower band is of a loose and marly nature inclosing hard lumps, which are generally of a lighter tint inside; it varies in thickness from 4½ to 7 feet, and sometimes it is only the central part of the band which is of a decided red colour, the upper and lower parts shading into pink and grey; *Holaster subglobosus* occurs both in and below this band, together with a few other fossils, but *Belemnitella plena* has not yet been found in Lincolnshire. The upper band consists of much harder and more evenly bedded chalk; it is generally about seven feet thick, and varies in tint from light-pink to yellowish-white; it is overlain by a course of hard white chalk surmounted by a band of soft mottled marl, which is usually two feet thick, and exhibits tints of red, grey, and buff. Above this are beds of hard yellowish-white chalk, which seem to represent the Melbourn rock; these contain *Inoceramus mytiloides* and *Rhynchonella Cuvieri*.

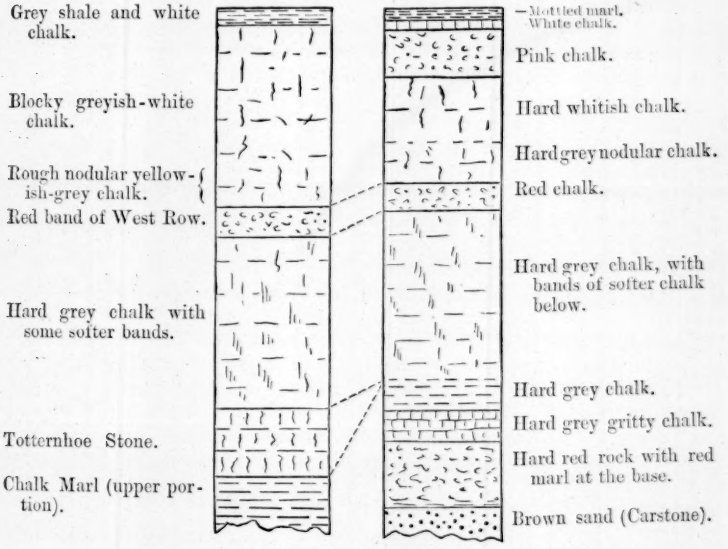
From the above description it will be seen that the West Row bed closely resembles the lower of the two red bands which are seen in the quarries near Louth, and as this occurs very nearly on the same horizon, I have little hesitation in correlating them with one another as homotaxial beds, though they may not be identical, because they do not appear to be continuous across the intervening space in Norfolk and Lincolnshire.

Figs. 1 and 2 are comparative vertical sections, showing the position of these bands of red chalk in Suffolk and Lincolnshire, both being drawn to a scale of 16 feet to the inch; the exact distance of the West Row chalk below the Melbourn rock can only be estimated approximately, but the Lincolnshire section is drawn from actual measurements taken in quarries at Louth. The upper portions of the two sections are similar, but the lower parts are very different. The base of the Chalk Marl is not seen in Suffolk, but the Marl is known to be between 60 and 70 feet thick, whereas in Lincolnshire there is only some 20 feet of grey and red chalk to represent the combined thickness of the Totternhoe Stone, Chalk Marl and Gault.

With regard to the horizontal extension of the red chalk in Suffolk

we obtained but little evidence. North of Mildenhall there is either a cross fault or a decided sinking of the beds in the direction of the strike, so that near Lakenheath the whole of the Lower Chalk lies below the surface of the Fens. The valley of the Little Ouse or Brandon River appears, however, to coincide with a line of fault, for the Lower Chalk comes to the surface again on the north side of the valley by Hockwold and Feltwell in Norfolk, and rises to a height of at least 60 feet above the level of the fen.

FIG. 1. SUFFOLK. FIG. 2. LINCOLNSHIRE.


Grey shale and white chalk.
Blocky greyish-white chalk.
Rough nodular yellowish-grey chalk.
Red band of West Row.
Hard grey chalk with some softer bands.
Totternhoe Stone.
Chalk Marl (upper portion).
Mottled marl. White chalk.
Pink chalk.
Hard whitish chalk.
Hard grey nodular chalk.
Red chalk.
Hard grey chalk, with bands of softer chalk below.
Hard grey chalk.
Hard grey gritty chalk.
Hard red rock with red marl at the base.
Brown sand (Carstone).

Scale—32 feet to one inch.

At Feltwell we were fortunate enough to find a small exposure of reddish chalk in the bank of a dry pond by the roadside, a quarter of a mile N.E. of St. Mary's Church; as it overlies a band of very hard nodular rock, below which a softer greyish white chalk is visible, there can be little doubt that it is the same band of red chalk, and that the section here is similar to that at West Row.

Beyond this we did not meet with any indications of red chalk, but it is quite possible for the band to extend some distance farther north without being seen, for large areas are covered with glacial and post-glacial deposits, and the pits near Stoke-Ferry are all either above or below the horizon on which I have placed this particular band.

At the same time it should be mentioned that the red bands in the Lincolnshire chalk only extend over an area of 12 or 15 miles in length, and are not found at the southern extremity of the Wolds. Whether they are really absent over the intervening space, or whether the beds themselves continue, but gradually lose their distinctive colour, and so become indistinguishable from the rest of the grey chalk, is a difficult point to decide, and one upon which I do not at present offer an opinion.

It only remains to add that nothing like the uppermost pink band of Lincolnshire was seen either in Suffolk or Norfolk, all the quarries exposing the horizon where it would occur exhibiting only whitish chalk, passing down gradually into grey chalk.

VI.—Comparative Studies upon the Glaciation of North America, Great Britain, and Ireland.

By Prof. H. Carvill Lewis, M.A., F.G.S.

(Abstract of a paper read at the Birmingham Meeting of the British Association, September, 1886.)

OBSERVATIONS extending over several years upon glacial phenomena on both sides of the Atlantic had convinced the author of the essential identity of these phenomena; and the object of this paper was to show that the glacial deposits of Great Britain and Ireland, like those of America, may be interpreted most satisfactorily by considering them with reference to a series of great *terminal moraines* which both define confluent lobes of ice and also often mark the line separating the glaciated from the non-glaciated areas.

The paper began with a sketch of recent investigations upon the glaciation of North America, with special reference to the significance of the terminal moraines discovered within the last few years. The principal characters of these moraines were given, and a map was exhibited showing the extent of the glaciated areas of North America, the course of the interlobate and terminal moraines, and the direction of striation and glacial movement. It was shown that apart from the great ice-sheet of North-eastern America, an immense lobe of ice descended from Alaska to Vancouver's Island on the western side of the Rocky Mountains, and that from various separate centres in the Cascade, Sierra Nevada, and Rocky Mountains, there radiated smaller local glaciers.

The mountains encircling the depression of Hudson Bay seemed to be the principal source of the glaciers which became confluent to form the great ice-sheet. In its advance this ice-sheet probably met and amalgamated with a number of already existing local glacial systems, and it was suggested that there was no necessity for assuming either an extraordinary thickness of ice at the Pole, or great and unequal elevations and depressions of land.

Detailed studies made by the author in Ireland in 1885 had shown remarkably similar glacial phenomena.

The large ice-sheet which covered the greater part of Ireland was composed of confluent glaciers, while distinct and local glacial systems occurred in the non-glaciated area. The principal ice-sheet resembled that of America in having for its centre a great inland depression surrounded by a rim of mountains.

These appear to have given rise to the first glaciers, which after uniting poured outwards in all directions. Great lobes from this ice-sheet flowed westward out of the Shannon and out of Galway, Clew, Sligo, and Donegal Bays, northwards out of Loughs Swilly and Foyle, and south-eastward out of Dundalk and Dublin Bays; while to the south the ice-sheet abutted against the Mullaghareik, Galty, and Wicklow mountains, or died out in the plains.

Whether it stopped among the mountains or in the lowlands, its edge was approximately outlined by unusual accumulations of drift and boulders, representing the terminal moraines. As in America, this outer moraine was least distinct in the lowlands, and was often bordered by an outer fringe of drift several miles in width.

South of an east and west line extending from Tralee to Dungarvan is a non-glaciated zone free from drift. Several local systems of glaciers occur in the south of Ireland, of which by far the most important is that radiating from the Killarney mountains, covering an area of 2000 square miles, and entitled to be called a local ice-sheet. Great glaciers from this Killarney ice-sheet flowed out of the fiord-like parallel bays which indent the south-westernmost coast of Ireland. At the same time the Dingle mountains, the Knockmealdown and Comeragh mountains, and those of Wexford and Wicklow furnished small separate glaciers, each sharply defined by its own moraine.

No evidence of any great marine submergence was discovered, although the author had explored the greater part of Ireland, and the eskers were held to be phenomena due to the melting of the ice-sheet and the circulation of subglacial waters. The Irish ice-sheet seemed to have been joined at its north-eastern corner by ice coming from Scotland across the North Channel. All the evidence collected indicates that a mass of Scotch ice, reinforced by that of Ireland and England, filled the Irish Sea, over-riding the Isle of Man and Anglesey, and extending at least as far south as Bray Head, south of Dublin. A map of the glaciation of Ireland was exhibited, in which the observations of the Irish geologists and of the author were combined, in which was shown the central sheet, the five local glacial systems, all the known striæ, and the probable lines of movement as indicated by moraines, striæ, and the transport of erratics.

The glaciation of Wales was then considered. Wales was shown to have supported three distinct and disconnected local systems of glaciers, while at the same time its extreme northern border was touched by the great ice-lobe of the Irish Sea. The most extensive local glaciers were those radiating from the Snowdon and Arenig region, while another set of glaciers radiated from the Plinlimmon district and the mountains of Cardiganshire, and a third system originated among the Brecknockshire Beacons. The glaciers from each of these centres transported purely local boulders and formed well-defined terminal moraines. The northern lobe, bearing granite boulders from Scotland and shells and flints from the bed of the Irish Sea, invaded the northern coast, but did not mingle with the Welsh glaciers. It smothered Anglesey and part of Carnarvonshire on the one side and part of Flintshire on the other, and heaped up a terminal moraine on the outer flanks of the north Welsh mountains. This great moraine, filled with far travelled northern erratics, is heaped up in hummocks and irregular ridges, and is in many places as characteristically developed as anywhere in America. It has none of the characters of a sea-beach, although often containing broken shells brought from the Irish Sea. It may be followed from the extreme end of the Lleyn Peninsula (where

it is full of Scotch granite erratics), in a north-easterly direction through Carnarvonshire, past Moel Tryfaen, and along the foot of the mountains east of Menai Strait to Bangor, where it goes out to sea, re-appearing further east at Conway and Colwyn. It turns south-eastward at Denbighshire, going past St. Asaph and Halkin mountain. In Flintshire it turns southward and is magnificently developed on the eastern side of the mountains, at an elevation of over 1000 feet between Minera and Llangollen, south-west of which place it enters England. There is evidence that where the ice-sheet abutted against Wales, it was about 1350 feet in thickness. This is analogous to the thickness of the ice-sheet in Pennsylvania, where the author had previously shown that it was about 1000 feet in thickness at its extreme edge and 2000 feet thick at points some eight miles back from its edge. The transport of erratics coincides with the direction of striæ in Wales as elsewhere, and is at right angles to the terminal moraines.

The complicated phenomena of the glaciation of England, the subject of a voluminous literature and discordant views, had been of high interest to the author, and had led him to redouble his efforts towards its solution. He had found that it was possible to accurately map the glaciated areas, to separate the deposits made by land-ice from those due to icebergs or to torrential rivers, and to trace out a series of terminal moraines both at the edge of the ice-sheet, and at the edge of its confluent lobes. Perhaps the finest exhibition of a terminal moraine in England is in the vicinity of Ellesmere in Shropshire. A great mass of drift several miles in width, and full of erratics from Scotland and from Wales, is here heaped into conical hills which enclose "kettleholes" and lakes, and have all the characters of the "kettle moraine" of Wisconsin. Like the latter, the Ellesmere moraine here divides two great lobes of ice, one coming from Scotland, the other from Wales. This moraine may be traced continuously from Ellesmere eastward through Madeley, Macclesfield, to and along the western flank of the Pennine chain, marking throughout the southern edge of the ice-sheet of northern England. From Macclesfield the same moraine was traced northward past Stockport and Staley Bridge to Burnley, and thence to Skipton in Yorkshire. North-east of Burnley it is banked against the Boulsworth Hills up to a height of 1300 feet in the form of mounds and hummocks. South and east of this long moraine no signs of glaciation were discovered, while north and west of it there is every evidence of a continuous ice-sheet covering land and sea alike. The striæ and the transport of boulders agree in proving a southerly and south-easterly direction of ice-movement in Lancashire and Cheshire.

From Skipton northward the phenomena are more complicated. A tongue of ice surmounted the watershed near Skipton, and protruded down the valley of the Aire as far as Bingley, where its terminal moraine is thrown across the valley like a great dam, reminding one of similar moraine dams in several Pennsylvania valleys. A continuous moraine was traced around this Aire glacier. Another greater glacier, much larger than this, descended Wensleydale and reached the plain of York. The most complex glacial movements in England occurred

in the mountain region about the Nine Standards, where local glaciers met, and were overpowered by the greater ice-sheet coming down from Cumberland. The ice-sheet itself was here divided, one portion going southward, the other in company with local glaciers, and laden with the well-known boulders of the "Shap granite," being forced eastward across Stainmoor Forest into Durham and Yorkshire, finally reaching the North Sea at the mouth of the Tees. The terminal moraine runs eastward through Kirkby Ravensworth towards Whitby, keeping north of the Cleveland Hills, and all eastern England south of Whitby, except Holderness, appears to be non-glaciated. On the other hand, all England north of Stainmoor Forest and the River Tees, except the very highest points, was smothered in a sea of ice.

There is abundant evidence to prove that the ice lobe filling the Irish Sea was thicker towards its axis than at its edges, and at the north at its southern terminus, and that it was reinforced by smaller tributary ice-streams from both England and Ireland. It may be compared with the glacier of the Hudson River valley in New York, each having a maximum thickness of something more than 3000 feet. The erosive power of the ice-sheet was found to be extremely slight at its edge, but more powerful farther north, where its action was continued for a longer period. Towards its edge its function was to fill up inequalities rather than to level them down. It was held that most glacial lakes are due to an irregular dumping of drift, rather than to any scooping action, observations in England and in Switzerland coinciding with those in America to confirm this conclusion. Numerous facts on both sides of the Atlantic indicate that the upper portion of the ice-sheet may move in a different direction from its lower portion. It was also shown that a glacier in its advance had the power of raising stones from the bottom to the top of the ice, a fact due to the retardation by friction of its lower layers. The author had observed the gradual upward passage of sand and stones in the Grindelwald glacier, and applied the same explanation to the broken shells and flints raised from the bed of the Irish Sea to the top of Moel Tryfaen, to Macclesfield and to the Dublin mountains. The occurrence of stratified deposits in connection with undoubted moraines was shown to be a common phenomenon, and instances of stratified moraines in Switzerland, Italy, America, and Wales were given. The stratification is due to waters derived from the melting ice, and is not proof of submergence. It was held that, notwithstanding a general opinion to the contrary, there is no evidence in Great Britain of any marine submergence greater than about 450 feet. It was natural that an ice-sheet advancing across a sea should deposit shell fragments in its moraine.

The broad principle was enunciated that wherever in Great Britain marine shells occur in glacial deposits at high levels,[1] it can be proved both by striæ and the transport of erratics that the ice advanced on to the land from out of the sea. The shells on Three Rock Mountain near Dublin, and in North Wales and Macclesfield, all from the Irish Sea; the shells in Cumberland transported from Solway Firth; those on the coast of Northumberland brought out of the North Sea; those

[1] *i.e.* higher than about 450 feet.

at Airdrie in Scotland carried eastward from the bottom of the Clyde; and those in Caithness from Moray Firth, were among examples adduced in proof of this principle. The improbability of a great submergence not leaving corresponding deposits in other parts of England was dwelt upon.

It was also held that there was insufficient evidence of more than one advance in the ice-sheet, although halts occurred in its retreat. The idea of successive elevations and submergences with advances and retreats of the ice was disputed, and the author held that much of the supposed interglacial drift was due to subglacial water from the melting ice.

The last portion of the paper discussed the distribution of boulders, gravels, and clays south of the glacial area. Much the greater part of England was believed to have been uncovered by land-ice. The drift deposits in this area were shown to be the result in part of great freshwater streams issuing from the melting ice-sheet, and in part of marine currents bearing icebergs during a submergence of some 450 feet. The supposed glacial drift about Birmingham, and the concentration of boulders at Wolverhampton, were regarded as due to the former agent; while the deposits at Cromer and the distribution of Lincolnshire chalk across southern England was due to the latter. The supposed esker at Hunstanton was believed to be simply a sea-beach, and the London drift deposits to be of aqueous origin. Thus the rival theories of floating icebergs and of land glaciers were both true, the one for middle and southern England, the other for Scotland, Wales, and the north of England; and the line of demarcation was fixed by great terminal moraines. The paper closed with an acknowledgment of indebtedness to the many geologists of England and Ireland, who had uniformly rendered generous assistance during the above investigation.

VII.—Note on the Facetted Pebbles from the Olive Group of the Salt Range, Punjab, India.

By R. D. Oldham, A.R.S.M.,
of the Geological Survey of India.

At the last meeting of the British Association certain facetted pebbles derived from the Olive group of the Salt Range, and presumably of glacial origin, were exhibited and commented on.[1] Some doubt appears to have been expressed as to their being due to glacial action. The following notes on these pebbles and the bed they were derived from may prove of interest.

The boulder bed of the Olive group in the Salt Range consists of a fine-grained, thin-bedded, shaly matrix, usually of that shade of green from which the name of the group is derived; through this are scattered blocks of hard crystalline and metamorphic rock, of all sizes, from an inch or less to several feet in diameter. They are too abundant for their occurrence to be explained by the action of drift wood, nor is there any sign of cabonaceous matter in the bed; there is no indication of volcanic action, and, as many of the fragments must have travelled scores, if not hundreds of miles, we are

[1] See Geol. Mag. 1886, Decade III. Vol. III. pp. 492, 494, 574.

compelled to allow that their occurrence in their present position is primarily due to the action of floating-ice. So much has long been allowed by all who know the bed.

Of these blocks of stone an appreciable proportion show a flattened striated surface, exactly like that produced by glacial action; but a peculiarity of this boulder bed is that a very large proportion of those blocks which show this feature are not striated on a single face only, but on several; and in some cases the original form of the pebble is so completely obliterated, and the facets meet on so clean-cut an edge, that the pebble assumes almost the appearance of a crystal. Something similar to this is known in the Boulder-clay of England; instances were quoted at the British Association, and I have myself seen a pebble from the Boulder-clay of the Midland Counties so striated on three faces; but these surfaces did not meet in a sharp edge, like those so commonly met with in the Salt Range specimens.

Having shown that the occurrence of these pebbles in their present position is due to the action of floating-ice, we have next to consider whether their peculiar form is also due to the action of ice, and if so whether as coast-ice or in the form of a glacier.

A suggestion was made at the British Association that the facetting might be due to the action of wind-blown sand; this, however, I cannot admit. Without egotism I may say that I have had opportunities of studying the erosive action of blown sand such as fall to the lot of few geologists. I have seen numbers of stones facetted by the sand blown against their different faces as they were overturned from time to time through one cause or another; but I have never seen anything which, to a practised eye, resembled these Salt Range pebbles any more than these latter do a crystal of felspar.

Where blown sand acts on a rock sufficiently hard or fine-grained, a polished surface, marked with numerous fairly parallel scratches in the direction of the prevailing wind, is produced. These scratches, however, could not be confounded with glacial striæ; for they are such as would result from particles of grit getting into an artificial polisher, and are very different from the clean and finely-cut scratches produced by glacial action. Where the rock is softer, it is often cut into grooves parallel with the direction of the prevailing wind; these, too, are not like the grooving produced by ice, but broad shallow channels separated by sharp-crested ridges, giving the rock an appearance as if it had been roughly dressed with a carpenter's gouge. In any case there is an entire absence of anything approaching to a sharp edge except in the direction of the wind, all angles oblique or transverse to that being rounded off. Now the facetted pebbles and boulders of the Salt Range show by the direction of the striæ on them that in almost every case the facets are due to some cause acting in a direction more or less transverse to the line along which they meet; consequently the facets cannot be due to the action of blown sand, which would have rounded off any angle so situated with reference to the direction in which the sand was drifted.

The number of stones showing one or more striated surfaces pre-

vents us from ascribing their origin to a movement of the soil-cap, while the steadiness of direction of the striæ on each face shows that the fragment must have been firmly held, and, in the case of the smaller ones, it is difficult to see how they could have been so held except by being imbedded in some material which, like ice, would adapt itself completely to the shape of the pebble.

The striated faces bear no resemblance to slickensides, and as the fragments seldom touch each other in the bed, but are separated by a greater or less thickness of the fine-grained matrix, any attempt to explain their origin by friction of the pebbles against each other subsequent to deposition is inadmissible; moreover, there is no exceptional disturbance of the beds, and the striated fragments are as common where they lie nearly horizontal as where they are tilted.

The only other agency by which the facets could have been produced is that which is at first sight suggested by the appearance of the pebbles, viz. *ice*, and it only remains to see whether this was in the form of coast-ice or glaciers. Here we must leave the domain of certainty, and enter on that of probability.

Prof. J. Milne has shown [1] that, as far as the live rock is concerned, many of the appearances usually considered characteristic of glacier action may be produced by coast-ice; but in the present case we are not concerned with what happens to the rock *in situ*, but with the effect produced on the loose pebbles and boulders caught up in the ice and ground on the solid rock. At first sight the number of striated faces on many of these pebbles would seem to point to the action of coast-ice, for, after every melting of the ice, the pebble would probably be fixed each winter in a fresh position, and offer a different face for abrasion; but it is doubtful whether the facets do not indicate a greater pressure and a greater constancy of direction of motion than could be given by coast-ice, and it is still more doubtful whether they could be produced during a single winter, which on this supposition is all that can be allowed for each facet.

A much stronger objection is the entire absence of any sign of the action of water on some of the pebbles. Had the facets been due to the action of coast-ice forming in winter and melting again in summer, the pebbles would every year have been exposed for a longer or shorter time to the action of waves, and the sharp, clean-cut junction of the facets which we find would have been more or less abraded; so that, if the shape of these pebbles is due to the action of coast-ice, it must have been perennial. I need but point out that coast-ice lasting through winter and summer implies a much severer climate than is needed to account for glaciers descending to the sea; *a priori* then the latter is the more probable hypothesis as requiring the least climatic change, besides being more in consonance with the evidence derived from the appearance and mode of occurrence of the boulders and pebbles showing signs of glacial action.

I have now shown that these boulder beds owe their origin primarily to the action of floating-ice, that the shape of the facetted fragments must be due to glacial action, that some at least of them

[1] Geol. Mag. Dec. II. Vol. IV. p. 293 (1877).

can never have been exposed to the action of waves on a sea-beach, and that consequently they must have been shaped either by perennial coast-ice rising and falling with the tides, or by a glacier which descended to the sea and there gave off icebergs. In either case they imply a change of climate which, if we bear in mind that the fragments have all come from the southwards, and in many cases from long distances, is of a degree and kind difficult if not impossible to explain in accordance with accepted theories.

VIII.—The Lower Palæozoic Rocks near Settle.

By J. E. Marr, M.A., F.G.S.

THE rocks of this area have been previously described by Professor Hughes (Geol. Mag. Vol. IV.), and some notes upon the same were subsequently submitted by myself to the British Association at York in 1881, and published in the Proceedings of the Yorkshire Geological and Polytechnic Society (Proc. Y. G. & P. S. n.s. vol. vii.).

Further work was carried on this year, in company with a party of Cambridge geologists, under the guidance of Prof. Hughes, and I have to thank him and them for much information, and for the opportunity of examining many specimens.

Firstly, I would correct one or two errors in my previous paper.

In the section in Austwick Beck, a considerable thickness of black shales is indicated between the conglomerate and the calcareous band with *Phacops elegans*. These black shales are really below the conglomerate, which latter appears in each limb of the anticlinal represented in the section, though *much attenuated*, and the black shales have yielded Bala fossils, including *Orthis testudinaria*, Dalm.

The only deposit between the conglomerate and the bed with *Phacops elegans* consists of two or three inches of leaden-grey shales, in which no fossils have been yet found.

The beds marked 5 in the section already referred to, and described as pale green shales, are really a portion of the same series as 6, and contain identical fossils with it, and the difference of colour is simply due to weathering.

We must therefore strike the beds 3 and 5 out of the list of those which I correlated with the Stockdale shales (Valentian), and admit that these are represented at Austwick only by the conglomerate, the leaden-grey shales, and the zone of *Phacops elegans*. That these thin beds represent the whole of the Valentian of other areas is doubtful, and it is possible that the representatives of the Coniston mudstones are here absent, and that the pale slates only are represented. That this may be the case is further indicated by the fact that *Phacops elegans* does occur in the higher Valentian beds, as in the Tarannon shales of Onny River, for I have recognized this species in the Jermyn Street Museum from that locality.

I may now proceed to a more detailed description of the different deposits in ascending order, as seen in the small valley near Austwick, through which Crummack Beck runs, and in the main Ribble Valley to the north of Settle.

As I do not wish to introduce new names, I shall speak of the beds

by the names given to similar beds in the Lake District, with which they have already been correlated, or ought, in our opinion, to be so.

A. *Coniston Limestone* series.—These beds are largely developed in the neighbourhood of Austwick. The probable succession is as follows:—

1. Calcareous blue shales, weathering olive-brown.
2. Ashes.
3. Blue, shivery shales.
4. Blue, flaggy, Brachiopod shales.

Conglomerate of succeeding series.

The calcareous blue shales (1) are well seen at the angle of the road below Norber Brow, where they are very fossiliferous. We have obtained from this locality the following fossils:—

Diplograptus (like *pristis*, His.).
Dicellograptus anceps, Nich.
Stenopora sp.
Tentaculites anglicus, Salt.
Ateleocystites sp.
Trinucleus seticornis, His.
Dindymene ornata, Linnrs. ?[1]
Cybele Loveni, Linnrs.
Lichas laxatus, M'Coy.
Turrilepas.
Phacops (*Pterygometopus*) sp.
Leptæna transversalis, Wahl.
,, *sericea*, Sow.
Orthisina sp.

The same beds appear to be represented in a stream south of Wharfe. From this locality fossils have been collected by the Rev. A. Pagan, amongst which are—

Ateleocystites sp.
Phacops (*Pterygometopus*) sp.

similar to those of Norber Brow.

The ashes (2) have as yet not furnished us with any fossils.

The blue shales (3) occur at Wharfe Mill Dam, and near a barn on the other side of the lane. In them we have found:—

Trinucleus seticornis, His.
Illænus Davisii, Salt.
Calymene Blumenbachii, Brongn.
Leptæna transversalis, Wahl.

The blue shales (4) which occur immediately below the conglomerate of Valentian age have yielded, as already stated, *Orthis testudinaria*, Dalm., along with a species of *Strophomena*.

B. *Stockdale Shale Series*.—I have nothing to add to the remarks made upon these beds, except to give a fuller list of fossils, which includes—

Petraia, sp.
Phacops elegans, Bœck & Sars.
Cheirurus bimucronatus, Murch.
Encrinurus punctatus, Brünn.
Leptæna quinquecostata, M'Coy.

All these occur in the thin bed of hard calcareous mudstone, which has been described as the zone of *Phacops elegans*, and which is almost entirely made up of fragments of Trilobites.

C. *Lower Coniston Flags*.—These beds immediately succeed the *Phacops elegans* zone of the preceding series, and are well developed in

[1] A fine specimen of *Dindymene* was discovered by Mrs. T. McK. Hughes, which is unfortunately somewhat distorted by cleavage. Until other specimens are found we refer it provisionally to *D. ornata*, Linnrs., though it will probably have to be separated eventually. Only eight body-rings occur.

the Crummack Valley. They consist of laminated blue, slightly gritty flags, with

Monograptus priodon, Bronn.
M. personatus, Tullbg.?
M. cultellus, Törnq.
Retiolites Geinitzianus, Barr.
Orthoceras.

D. *Grits.*—These beds, the Grits A c 2 of Prof. Hughes' section, are largely developed in both valleys. They have as yet furnished no fossils.[1]

E. *Upper Coniston Flags.*—Seen at Studrigg, on the east side of the Crummack Valley, and in Dryrigg, Arco Wood, and Combs Quarries in Ribblesdale. They resemble, in lithological characters, the Lower Coniston Flags, but the fossils are different.

At Studrigg *Monograptus Roemeri*, Barr., was found by one of Prof. Hughes' party, and the Ribblesdale quarries have yielded:—

Monograptus colonus, Barr.
,, *bohemicus*, Barr.
Favosites fibrosus, Goldf.
,, *alveolaris*, Goldf.
Actinocrinus pulcher, Salt.
Pentamerus ?
Orthoceras primævum, Forbes.
Trochoceras giganteum, Sow.

F. *Grits.*—Mentioned by Prof. Hughes as occurring above the Flags (E) at Studfold Low Pasture, on the east side of Ribblesdale. These are the highest Lower Palæozoic beds seen in this area.

Comparison with other Areas.—The general resemblance between the beds of this district and those of the Lake District, whether we take into account lithological or palæontological characters, is so striking, that there is little or no difficulty in correlating the beds of the two areas. The following table shows the probable equivalents:—

Settle District.	Lake District.
Coniston Limestone Series.	Coniston Limestone.[2]
Absent?[3]	Ashgill shales.
Absent?	Coniston Mudstones.
Conglomerate?	Pale slates.
Phacops elegans zone?	
Lower Coniston Flags.	Brathay Flags.
Grits.	Lower } Coldwell beds.
Moughton Whetstones?	Middle }
Upper Coniston Flags.	Upper Coldwell beds.
Grits (Studfold).	Coniston Grits.

The most interesting feature of the rocks of the Settle District is the approach to the characters of the Scandinavian beds.

The Coniston Limestone series is much more shaly than the typical

[1] It is possible that the remarkable whetstones near the head of the valley, which have not been detected in situ, are interstratified with the grits. Amongst the fossils contained therein are:—

Monograptus dubius, Suess.
M. Nilssoni, Barr.
M. uncinatus, Tullb.?
Orthoceras primævum, Forbes.

[2] The beds with *Dicellograptus anceps* have not been detected in the Lake District proper, but similar beds occur at Melmerby Scar, on the west slope of the Pennines.

[3] Unless the beds with *Orthis testudinaria*, immediately below the conglomerate, are the equivalents of the Ashgill shales.

Coniston Limestone, and indeed is intermediate in lithological character between that Limestone and the Trinucleus Shales of Sweden. Palæontologically it is connected with the latter by the occurrence within it of *Diplograptus* like *pristis*, *Dicellograptus anceps*, *Trinucleus seticornis*, *Dindymene ornata ?*, *Cybele Loveni*, and *Turrilepas*.

The Lower Coniston Flags have the fauna of the Cyrtograptus Shales, though *Cyrtograptus* has not yet been found in them. Our fossils are derived from near the base of this series, and that they occur in beds about the horizon of the lower part of the Cyrtograptus Shales is possibly indicated by the occurrence of *Monograptus cultellus*, of which, however, only one specimen has hitherto been found in the Settle District. A further examination of these Lower Coniston Flags, at points more remote from the base, will probably be rewarded by the discovery of other species of Graptolites.

That the Moughton Whetstones are really intermediate in position between these Lower Coniston Flags and the flags in the quarries of Arco Wood, Dryrigg, etc., seems proved by the occurrence in them of *Monograptus dubius*, *M. uncinatus?* and *M. Nilssoni*, all of which are found at the base of the Cardiola beds of Sweden, whilst the higher parts of the Cardiola beds contain fossils identical with those of Arco Wood, etc., including *Monograptus colonus*, and *M. bohemicus*. The zone with *M. dubius*, etc., has, so far as I am aware, been hitherto unrecorded in Britain, and the probable corresponding beds in the Lake District are not of a nature suitable for the preservation of Graptolites.

The Swedish affinities of these Settle rocks will probably be further proved, when more work has been carried on in the district, and from the simplicity of the sections, the area can confidently be recommended to the notice of any geologist who wishes, by patient work, to assist in establishing the zones of the Lower Palæozoic rocks of our country.

NOTICES OF MEMOIRS.

Papers read before Section C. (Geology) British Association Meeting, Birmingham, 1886.

I.—Manganese Mining in Merionethshire. By C. Le Neve Foster, D.Sc., F.G.S.

MANGANESE ore is now being worked in the Cambrian rocks at several places near Barmouth and Harlech. It occurs in the form of a bed varying from a few inches to three feet in thickness; the average thickness is one foot to one foot and a half. The undecomposed ore contains the manganese in the form of carbonate, with a small proportion of silicate; but at the outcrop it is changed into a hydrated black oxide. Some of the outcrops of the manganese bed are erroneously marked on the Geological Survey Maps as mineral veins, though Sir Andrew Ramsay was of opinion that the deposits were not true lodes. Recent workings show plainly that the deposits are truly stratified beds, or possibly various outcrops of one and the same bed, extending over a considerable area.

The ore contains from 20 to 35 per cent. of metallic manganese, and is despatched to Flintshire and Lancashire for the manufacture of ferromanganese. The new Merionethshire mines are the first instance of workings for carbonate of manganese in the British Isles.

II.—On the Stratigraphical Position of the Salt Measures of South Durham. By G. A. Lebour, M.A., F.G.S., Professor of Geology in the Durham College of Science, Newcastle-upon-Tyne.

THE beds above the main mass of the Magnesian Limestone in Durham are seldom exposed at the surface, as the south of the country is covered by a thick spread of drift. The presence of salt deposits having, however, been proved some years ago in the adjoining part of Yorkshire near Middlesbrough, several borings for working them in the form of brine were soon put down in the flat country between the Tees and the coast south of Seaton Carew. There are now altogether some fifteen or sixteen such borings, most of which have reached beds of salt at depths varying from 600 feet to over 1200 feet. These have thrown much light upon the rocks, hitherto scarcely known in this part of England, which lie between the Rhætic and the great Permian Magnesian Limestone of Durham. The author exhibited sections of these beds, and gave reasons for suggesting that much of the Salt Measures of this district is probably the representative of the Upper Permian or *Rauchwacke* of Germany.

The following table summarizes fairly the classification tentatively suggested by the author :—

Avicula contorta beds (proved in Eston shaft and boring) ...	Rhætic.
7. Red and green marls, with gypsum (known only south of Tees)	Upper Trias.
6. Red sandstone	
Unconformity (?)	
5. Red sandstones and marls	(? Lower) Trias.
Unconformity (?)	
4. Red marly sandstones, marls, with lenticular beds of anhydrite, gypsum, and salt, and fœtid limestone in variable bands towards the base	Upper Permian. (Rauchwacke).
3. Main Magnesian Limestone	Middle Permian.
2. Marl slate with fish-bed	
1. Yellow sands	Lower Permian.
Unconformity.	
Carboniferous Rocks.	

III.—Geysers of the Rotorua District, North Island of New Zealand. By E. W. Bucke.

THE author of this paper has recently returned from the Lake district of New Zealand, where he spent eighteen months, and had exceptional opportunities for making observations upon the volcanic phenomena of the district. The largest geyser in New Zealand, that of the White Terrace of Rotomahana, is now destroyed; the three next in size are those of Pehutu, Waikiti, and Wairoa, all of which are situated close together at the back of the native village named Whakarewarewa, about three miles to the south of the Rotorua township, and these are particularly described in the present communication. The author was able to determine by soundings the depth of the tubes of several geysers of this district, and in the case of an extinct one, that of Te Waro, he was let down the tube. He found that this tube, at a depth of 13 feet from the surface, opened into a chamber 15 feet long, 8 feet broad, and 9 feet high, and that from one end of this chamber another tube led downwards to an undetermined depth.

Living entirely among the natives for many months, and speaking their language, the author was able to test the power claimed by the natives of being able to predict the outbursts of the geysers. He is convinced that by constant observations on the direction of the wind and the condition of the atmosphere, the natives have learnt to prognosticate the movements in all these hot springs with wonderful accuracy. He was also able to prove that during the whole time of his residence in the district certain of the geysers were only in eruption when the wind blew from a particular quarter.

IV.—On an Accurate and Rapid Method of Estimating the Silica in an Igneous Rock. By J. H. Player, F.G.S., F.C.S.

THIS paper describes a method of estimating the silica in igneous rocks by

1. Fusing the finely ground rock with a flux prepared by mixing carbonates of potash and soda and nitrate of potash.
2. Disintegrating the glass so obtained by the action of strong nitric acid.
3. Driving off nitric acid at a temperature just below 250°, thus rendering all silica insoluble.
4. Treating with hydrochloric acid, to leave the silica with some impurity, for weighing after calcination.
5. Separating the impurity by means of ammonium fluoride and weighing it.

REVIEWS.

Observations sur les Groupes sédimentaires les plus anciens du nord-ouest de la France. Par M. Hébert. (Extrait des Comptes rendus des Séances de l'Académie des Sciences, tom. ciii., Séance du 26 Juillet, 1886.)

IN this memoir, Professor Hébert submits to the Academy a view of the Geology of North-Western France which differs in some points from previous interpretations. Brittany and Western Normandy present difficulties such as have perplexed British geologists in many of the tracts occupied by the older rocks. French writers are agreed that in North-Western France there are (omitting the true crystalline schists) (1) a granite, (2) a great formation of phyllite, and (3) a series of purple conglomerates and (?) shales (*schistes*). The last-named group is overlain by the *Grès Armoricain*, and over this sandstone come shales and slates, with *Acidaspis Buchii*, and more than one species of *Placoparia*. These *Placoparia* beds, with the same *Acidaspis*, occur in our Salopian area, not far above the grits of the Stiper Stones; so that the *Grès Armoricain* may be safely regarded as Arenig. But below this horizon, the interpreters of Brittany geology find the materials for widely diverging opinions. The theory of M. Hébert may be thus summarized.

The oldest of the three rock-masses is the granite. It furnishes numerous rolled blocks to a conglomerate in the phyllite series, and it never penetrates the adjoining strata in veins. At its junction with the phyllite, the granite is in the state of sand, and the phyllite also is

decomposed. The stratified rocks of the district are indeed penetrated by veins; but these consist of "*granulite*" (not granite), and they ramify through both granite and sedimentaries alike; in the former they are called pegmatite, in the latter granulite proper. They behave like true eruptive rocks, and are welded to the walls of the adjacent phyllite, which they harden and modify at the contact.

The phyllite is next in age, but is older than the purple series. M. Hébert submits twofold evidence for this contention. (1) The purple series includes beds of rounded fragments of a quartz which is identical with certain quartz-veins in the phyllite. One of these varieties, a black quartz, is at Coutances quarried in the phyllite, and is found not far off in the conglomerate of the purple group. (2) While the phyllite usually dips at high angles, or is tilted to the vertical, the purple series lies at much lower dips, and these relations are sometimes seen where the two groups are in contact. M. Hébert concludes that the phyllites are Archæan; but he would confine the term to this formation, which he regards as the oldest sedimentary group, "le premier *terrain*." The granite and the crystalline schists are thus left unclassified. The phyllite is regarded by M. Hébert as the equivalent of the less crystalline of the Pre-Cambrian rocks of Anglesey, and of the beds which, according to Prof. Green, underlie the Cambrian conglomerates of Llanberis.

The purple conglomerates and (?) shales, separated by a marked discordance from the phyllite series, are placed in the Cambrian.

It would be rash for a stranger to the district to express an opinion on a question of such evident difficulty as the one before us. M. Ch. Barrois, writing only last year (1885), is at variance with M. Hébert on the main points discussed, and he will doubtless take up the cudgels which he can wield so well. The issue, whatever it be, should have an important bearing on the geology of the Channel Islands, recently brought to our notice by the Rev. Edwin Hill, and it may tend to smoothe, or the reverse, the troubled waters of the Archæan controversy.

It would aid our future studies in this direction if a precise meaning were attached to certain terms used in M. Hébert's paper, especially to the words "phyllites" (les phyllades), "schist," and "grauwacke."

CH. CALLAWAY.

REPORTS AND PROCEEDINGS.

I.—November 17, 1886.—Prof. J. W. Judd, F.R.S., President, in the Chair.—The following communications were read:—

1. A letter from the Lieutenant-Governor of the Falkland Islands, communicated by H.M. Secretary of State for the Colonies:—

"Government House, Stanley, Falkland Islands,
3rd June, 1886.

"MY LORD,—I regret to have to report that a slip of the peat-bog at the back of the town of Stanley, similar to that which occurred in November, 1878,[1] but about two hundred yards to the

[1] See Quart. Journ. Geol. Soc. vol. xxxv. Proc. p. 96.

westward of the scene of that accident, took place last night. A stream of half-liquid peat, over a hundred yards in width, and 4 or 5 feet deep, flowed suddenly through the town into the harbour, blocking up the streets, wrecking one or two houses in its path, and surrounding others so as completely to imprison the inhabitants. Fortunately, as the night was wet and stormy, almost every one was within doors, and the few who were in the wrecked houses escaped in time. One child was, unfortunately, smothered in the peat, whose body has been recovered, but no other casualties are known to have occurred. An old man is, however, reported to be missing this morning, and it is feared he may also have perished, as part of his house is almost filled with peat. . . . . The slip was caused, apparently, by the unusually heavy rains which have fallen during the last few days, and which the drains constructed by Mr. Bailey, the Surveyor, in 1878, proved insufficient to carry off. Deeper and wider cuttings will now be made, and I trust that the recurrence of any similar catastrophe may thus be prevented. The town of Stanley is, however, from its situation and the mass of peat-bog on the high ground behind it, always to some extent exposed to danger of this nature in times of unusually heavy rainfall.—I have, etc.

"(Signed) ARTHUR BARKLY.

"The Right Hon. Earl Granville, K.G.. &c., &c., &c."

2. "On the Drifts of the Vale of Clwyd, and their relation to the Caves and Cave-deposits." By Prof. T. M'Kenny Hughes, M.A., F.G.S.

The author divided his subject as follows:—I. Introductory Remarks; II. The Drifts, viz. (i.) The Arenig Drift, (ii.) The St.-Asaph Drift, (iii.) The Surface-Drifts; III. The Caves, viz. (i.) The Caves themselves, (ii.) The Cave-Deposits; IV. Conclusion.

He exhibited a table showing the tentative classification he proposed. II. (i.) The Arenig Drift, he said, might be called the *Western Drift*, as all the material of which it was composed came from the mountains of Wales; or the *Great Ice-Drift*, as it was the only Drift in the vale which contained evidence of direct ice-action. He traced its course from the Arenig and Snowdon ranges, by striæ on the solid rock and by the included fragments, a large proportion of which were glaciated. There are no shells in this drift.

II. (ii.) The St.-Asaph Drift might, he said, be called the *Northern Drift*, as it was the deposit in which fragments of north-country rocks first appeared; or the *Marine Drift*, as it was, excepting the recent deposits at the mouth of the estuary, the only drift in the vale which showed by its character and contents that it was a sea-deposit. It contained north-country granites, flints, and sea-shells, of which he gave lists. Most of them are common on the adjoining coast at the present day, a few are more northern forms. None of the rocks are striated, except those derived from the Arenig Drift (i.).

II. (iii.) The Surface-Drifts included the older and newer alluvia of the rivers, the Morfa Rhuddlau Beds or estuarine silt, the recent shore-deposits or Rhyl Beds, and all the various kinds of deposits known as talus, trail, rain-wash, head, run-of-the-hill, etc., of which,

in so long a time, very thick masses have accumulated in many places. He explained some methods of distinguishing gravels according to their origin.

Turning to the subject of Caves, he thought they should be careful not to confound (III. i.) the question of the age and origin of the caves themselves with (III. ii.) that of the deposits in the caves. He then described some of the more important caves of the district, explaining the evidence upon which he founded the opinion that the deposits in Pontnewydd Cave were postglacial palæolithic. He arrived at the same conclusion with regard to the deposits in the Ffynnon Beuno Caves. Combating the objections to this view which had recently been urged, he pointed out that the drifts associated with the deposits in those caves cannot have ben formed before the submergence described under II. (ii.), because they contained north-country fragments and flints, and that, even if they were of the age of the submergence, they would not be preglacial; that they cannot have been formed during the submergence, as the sea would have washed away the bones, etc., from the mouth of the cave, and its contents must have shown some evidence of having been sorted by the sea. He considered that the greater part of the material that blocked the upper entrance of the upper cave belonged to the surface-drifts described under II. (iii.), and were, as they stood, almost all subaerial.

He further pointed out that, so far as palæontologists had been able to lay before them any chronological divisions founded on the mammalia, the fauna of the Ffynnon Bueno Caves agreed with the later rather than with the earlier Pleistocene groups.

II.—December 1, 1886.—Prof. J. W. Judd, F.R.S., President, in the Chair.—The following communications were read:—

1. "On a new Genus of Madreporaria — *Glyphastræa*, with remarks on the *Glyphastræa Forbesi*, Edw. & H., sp., from the Tertiaries of Maryland, U.S." By Prof. P. Martin Duncan, M.B., F.R.S., F.G.S., etc.

The specimens of *Septastræa Forbesi*, Edw. & H., were examined many years ago, and the author had always a doubt about their generic position. Lately a very well-preserved specimen has been received, which when compared with those in the National Collection and carefully studied, is found to have a columella and a remarkable dome of endotheca at the top of the base of the calicular fossa, resembling the well-known structure in *Clisiophyllum*.

Two opposite primary septa become very narrow, extend inwards, form, with another structure, a narrow linear columella, and thus produce the appearance of a continuous lamella. The other primaries and some of the secondary septa reach this long structure, and the endotheca stretches between the ends of the septa, their sides, and the columella, and closes up the interseptal loculi. The epithecal dissepiments are dome-shaped at the base of the calice, and are ornamented with sparsely distributed granules: superficially a corresponding granulation occurs on the narrow and also on the wide marginal parts of the septa.

There is a groove between the calices, and it corresponds with the imperfect junction of the corallite walls. Fissiparity occurs and also gemmation.

Natural sections show a narrow ribbon-shaped columella.

The examination of the perfect specimens proves that whilst they cannot be understood without sections, sections alone would never enable the palæontologist to realize the elaborate superficial structures. It was pointed out that weathering utterly destroyed the generic and specific characters, and the author ventured to caution the students of the Madreporaria against describing weathered and worn specimens of any types, and not to depend entirely upon sections.

The new genus *Glyphastræa* includes Astræidæ of the Goniastræoid alliance with fissiparity, gemmation and a ribbon-shaped columella. *Septastræa Forbesi* becomes *Glyphastræa Forbesi*, Edw. & H., sp.

2. "On the Metamorphic Rocks of the Malvern Hills." Part I. By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines.

Part I. is the result of conclusions arrived at in the field. Part II. will be devoted to a microscopic description of the rocks.

The author referred especially to the paper by the late Dr. Holl, whose work he, in the main, confirmed. Dr. Holl's object was to demonstrate that the rocks which had hitherto been treated as syenite, and supposed to form the axis of the hills, were in reality of metamorphic origin, and belonged to the Pre-Cambrian. Mr. Rutley restricted his observations to the old ridge of gneissic syenite, granite, etc., which constitutes the main portion of the range, and reversing the order of his predecessor, commenced at the north end of the chain.

He considers that the beds of crystalline rock, mostly of a gneissic character, in the old ridge have been disposed in a synclinal flexure, which stretched from the north end of the chain to the middle of Swinyard's Hill, where they receive an anticlinal flexure, and are faulted out of sight. The length of this synclinal fold would be over $5\frac{1}{2}$ miles. The lithological evidence is in favour of the rocks forming the north part of Swinyard's Hill being a repetition of those on the Worcestershire Beacon. We might expect to find the older beds having the coarsest granulation, and being even devoid of foliation, and this is what occurs on the Malverns, where the northern hills are made up of the coarsest rocks, with finer schistose beds towards the south; the exception is at Swinyard's Hill; hence there are two groups of coarsely crystalline rocks at either extremity of the presumed synclinal. The contrast between these and the fine-grained rocks of the other portions of the range has already attracted attention. The most northern of the coarse-grained masses is cut off towards the south by a fault near the Wych, while the other lies between a fault on the north side of the Herefordshire Beacon and the before-mentioned fault on Swinyard's Hill.

The metamorphic rocks of the Malverns seem, therefore, to be divisible into three series extending from the North Hill to Key's End. A Lower, of coarsely crystalline gneissic rocks, granite, syenite, etc., a Middle, of gneissic, granitic and syenitic rocks of medium and fine texture, and an Upper, of mica-schist, finely crystalline gneiss, etc. A diagrammatic section shows the distribution of these; the northern

block, extending as far as the Wych, consists of the Lower and the lower part of the Middle; the central block, from the Wych to the fault in Swinyard's Hill, consists chiefly of the Lower and upper Middle, but with a portion of the Lower at the south end. The southern block, south of the fault on Swinyard's Hill, consists wholly of the Upper series.

How far the foliation of these rocks and their main divisional planes represent original stratification must, the author thought, remain an open question. It has been held that the strike of foliation lies parallel to the axes of elevation; but this is far from being the case in the Malverns. Still, a once uniform strike may have been dislocated by repeated faulting.

The author further discussed the general question of how far foliation may or may not coincide with planes of sedimentation. He admitted that the absolute conversion of one rock into another by a process of shearing has been shown to occur, but doubted its application in this case. Although he is inclined to believe that the divisional planes, with which the foliation appears to be parallel, may be planes of original stratification, yet, as a matter of fact, they are nothing more than *structural planes of some sort*, between which the rocks exhibit divers lithological characters.

3. "On Fossil Chilostomatous Bryozoa from New Zealand." By Arthur W. Waters, Esq., F.G.S.

The fossil Bryozoa described in the present paper are from the localities of Petane, Waipukurau, Wanganui, and some simply designated as from the neighbourhood of Napier. The first three represent deposits of a well-known position, which was considered Miocene by Tenison-Woods, but which Professor Hutton (Quart. Journ. Geol. Soc. vol. xli.) has more recently called Pliocene. Some others, sent over as from "Whakati," are thought to be from Waikato.

The genus *Membranipora*, which is largely represented from near Napier, is not one of the most useful palæontologically, because the shape of the opesial opening only, and not the oral, is preserved, and also the appearance of the zoœcia is often remarkably modified by the ovicells, which, however, are frequently wanting, and in many well-known species have never been found.

The author pointed out that in the commoner and best-known species of Bryozoa the amount of variation is recognized as being very great, and considered that in the face of this there is too great a tendency to make new species on slight differences which may be local variations, and that even in some cases, instead of the description referring to a species, it may be that only a specimen has been described.

A list of New-Zealand Bryozoa has been drawn up by Professor Hutton, and our knowledge of the New-Zealand and Australian Bryozoa is being constantly increased by MacGillivray, Hincks, and others; nevertheless, enough is not yet known to fix the exact age by means of the Bryozoa alone, but the large number of species entirely identical with those living in the neighbouring seas, and the general character of the others, show that the deposits must certainly be considered as of comparatively recent date.

Out of the 78 species or varieties, 61 are known living, 29 of these

from New-Zealand seas, 48 from either New-Zealand or Australian waters, and 28 have been found fossil in Australia. Judging from these alone, it would seem that some authors have assigned too remote an age to the deposits. The new forms described were:—

Membranipora occultata
Monoporella capensis, var. *dentata*.
—— *waipukurensis*.
Micropora variperforata.
Mucronella tricuspis, var. *waipukurensis*.
—— ——, var. *minima*.
—— ——*firmata*.
Porina grandipora.
Lepralia semiluna, var. *simplex*.
—— *bistata*
Schizoporella cinctipora, var. *personata*.
—— *tuberosa*, var. *angustata*.
Cellepora decepta.
———, sp.

CORRESPONDENCE

ON THE OCCURRENCE OF PHOSPHATIC NODULES IN THE LOWER GREENSAND, EAST OF SANDOWN.

Sir,—When working near Sandown, in company with Mr. H. Keeping, we observed several beds of phosphatic nodules in the Lower Greensand; these do not appear to have been previously noticed, no mention being made of them in the Survey or other memoirs on the district. Mr. Bristow describes some "concretionary masses or bodies" which occur in Fitton's bed No. xvi. at Rocken End, near Black Gang: these may represent some of the nodule beds at Sandown.

The phosphates are of a light brown colour, and occur at four horizons. The three lowermost are very distinct, and come between 160 and 200 feet from the top of the Lower Greensand, whilst the fourth is some distance higher up. The second band from the bottom is about seven inches in thickness, and from it the following fossils were obtained:—*Ammonites biplex*, Sow. *A. cordatus*, Sow. *Pleurotomaria* sp. *Cardium striatulum?* *Lucina* sp. *Myacites* sp. *Cytherea rugosa?* *Arca contracta*, Phill. They are all much rounded, and difficult to determine. In this bed there are also fragments of various rocks, such as quartzite, lydian stone, etc., the first of which greatly resembles those in the Budleigh Salterton pebble bed. The nodules in the upper band are much smaller, and are associated with a great many quartz pebbles.

The phosphates and fossils of the lower beds are very similar to those of Brickhill and Potton in Bedfordshire, Wicken in Cambridgeshire, and Tealby in Lincolnshire. The second bed noticed above is sufficiently thick to be worked for commercial purposes, but the strata dip at such a high angle, that but little of the phosphates could be profitably obtained.

The Geological Survey is now engaged in the district, and the exact horizons at which the nodules occur will no doubt be given in their sections.

H. Woods.

Woodwardian Museum, Cambridge.

THE PEA GRIT OF LECKHAMPTON HILL.

Sir,—The letter of my friend, Mr. E. Wethered, in the last number of the Magazine, requires some notice from me. Mr. Wethered takes exception to a remark in my paper on the basement-beds of the Inferior Oolite, that the beds between the Pea Grit proper and the

Cephalopoda-bed have been included by the late Dr. Wright and others in their published works in the term "Pea Grit," and he refers me to the paper by Dr. Wright on the so-called sands of the Inferior Oolite" as showing that I am in error. I have referred to the paper cited, and find that in the section (Fig. 1) only one bed is shown as including the Pea Grit and the underlying beds, although in the explanation at foot it is called "Pea Grit and ferruginous oolite," and marked A B C; but the description in the following page is headed "Pea Grit (Inferior Oolite)," and under this heading the beds A B and C are described: the description of A and B appears, however, to be substantially the same.

In Dr. Wright's latest work "Monograph on the Lias Ammonites" the section of Leckhampton Hill is repeated (fig. 11, page 151); and on reference to the description (p. 152), I find the heading is "Pea Grit (Zone of *Harpoceras Murchisoniæ*, Inferior Oolite)," the subdivision being the same as before, and the description being wholly under this heading.

I think the meaning is clear, namely, that it was intended that the term "Pea Grit" should apply to all the beds, although, for the purpose of giving a more accurate description, a subdivision of them was convenient.

Mr. Wethered refers me to Dr. Wright's section of Cleeve Hill, but the extract is incorrectly given, doubtless an error in printing.

For—	
Pea Grit	21ft. 30 in.
Coarse ferruginous oolite	22ft. 5 in.
Read—	
Peat Grit, No. 21	30ft. 0 in.
Coarse ferruginous oolite	5ft. 0 in.

The correct reading confirms my statement, except as regards the lower 5ft.

The section of Cleeve Hill is also repeated in the monograph on the Lias Ammonites (fig. 12, p. 155), and in the description (p. 161) the beds are called "Pea Grit," and the three subdivisions are described in much the same language as is used in the description of the beds at Leckhampton.

EDWIN WITCHELL.

CORRECTION OF MIOCENE INSECTIVORA.

SIR,—With your permission I will avail myself of the GEOLOGICAL MAGAZINE to correct an error into which I have been led by the writings of others in part i. of the "Catalogue of Fossil Mammalia in the British Museum" (1875).

On page 19 of that volume I followed Dr. O. Fraas in identifying the Auvergne *Plesiosorex soricinoides* (*Erikaceus soricinoides*, of Blainville) with *Parasorex socialis*, Meyer, of Steinheim. Having recently, however, had cause to consider further the affinities of the Miocene Insectivora, I have been led from an examination of the figures given by Fraas and De Blainville to the conclusion that the identifications made by the former writer are totally erroneous. The Steinheim *Parasorex socialis* is, as Fraas states, closely allied to

[1] "Fauna von Steinheim," p. 4 (1870).

Tupara, while *Plesiosorex soricinoides* is a totally different form, whose affinities, as stated by Pomel, are rather with *Myogale*. I am further led to conclude that Fraas' identification of *Erikaceus arvernensis* of De Blainville, with *Plesiosorex soricinoides* is likewise erroneous, and that the fauna is probably identical with *E. arvernensis* of Gervais.[1]

The specimen entered in the Museum Catalogue under the name *Plesiosorex* must therefore be named *Parasorex*, and the former genus referred to the *Talpidæ*. This error will be noticed in the supplement to be published in part v. of the Museum Catalogue; but as the publication of that part will be several months hence, I have thought it advisable to correct the error as soon as possible.

HARPENDEN, *Dec.* 10, 1886. R. LYDEKKER.

ON THE OSBORNE BEDS.

SIR,—I wish to correct a mis-statement of my views respecting the position of the Osborne Beds, which appears in the Report of the International Geological Congress for 1885, and also I find is reproduced in Mr. Jukes-Browne's new Handbook of Historical Geology. My opinion has always been that the Osborne Beds should have been a part of the Bembridge Series, and not a separate member.

Woodwardian Museum, Cambridge. H. KEEPING.

THE COLLINGHAM OR SCARLE BORING.

SIR,—In the recently issued Report of the British Association for 1885, pp. 388, 389, the original inaccurate account of this boring is reproduced, and I am credited with the alternative figures given in a second column.

Permit me to state that I have published no account of the boring, and that the figures alleged to be mine do not coincide with the section preserved among my papers, viz.:—

	Gravel	21 feet.
	Lias	29
	Rhætic	15
	Keuper Marls	688
	Keuper Sandstone	205½
	Bunter "Pebble Beds"	319
	Lower Bunter	223
Upper Permian 380½	Marls	118½
	Limestone	43½
	Marls	150
	Limestone	68½
Lower Permian 139	Sandstone	20
	Marl Slates	118
	Breccia	1
	Coal Measure Shales	12
		2032

The site is not in the parish of Scarle, Lincolnshire, but in Collingham, Notts.

W. H. DALTON, F.G.S.,
Late H.M. Geological Survey.

[1] See "Cat. Foss. Mamm. Brit. Mus." pt. i. pp. 17, 18.